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ABSTRACT

This curriculum guide contains 18 units for a course to assist apprentices in learning the pipefitting trade. Introductory materials include lists of suggested audiovisual materials, competencies, and textbooks and approximate times for each unit. Each instructional unit includes some or all of the following components: competencies, instructional objectives, learning activities, application exercises, evaluation/checkout, list of equipment, list of learning materials, audiovisual materials, and resources. Answers to exercises and evaluations are appended to each unit. Units cover introduction to the trade; brazing and soldering; chemical handling; hot water heating systems; hydraulics; insulation; mathematics; physics; pipe hangers and supports; pipe welding and welding--basic skills; pneumatics; process pipe drafting; process piping fabrication; process steam systems; refrigeration and air conditioning; rigging; templet development; and valves, packings, and gaskets. Copies are provided of the apprentice guides for each of the units. These list the competency; instructional objectives; learning activities; and evaluation/checkout. An attached handbook for supervisors includes a series of application exercises for the apprentice. They correspond with competencies and learning objectives learned in the classroom. (YLB)

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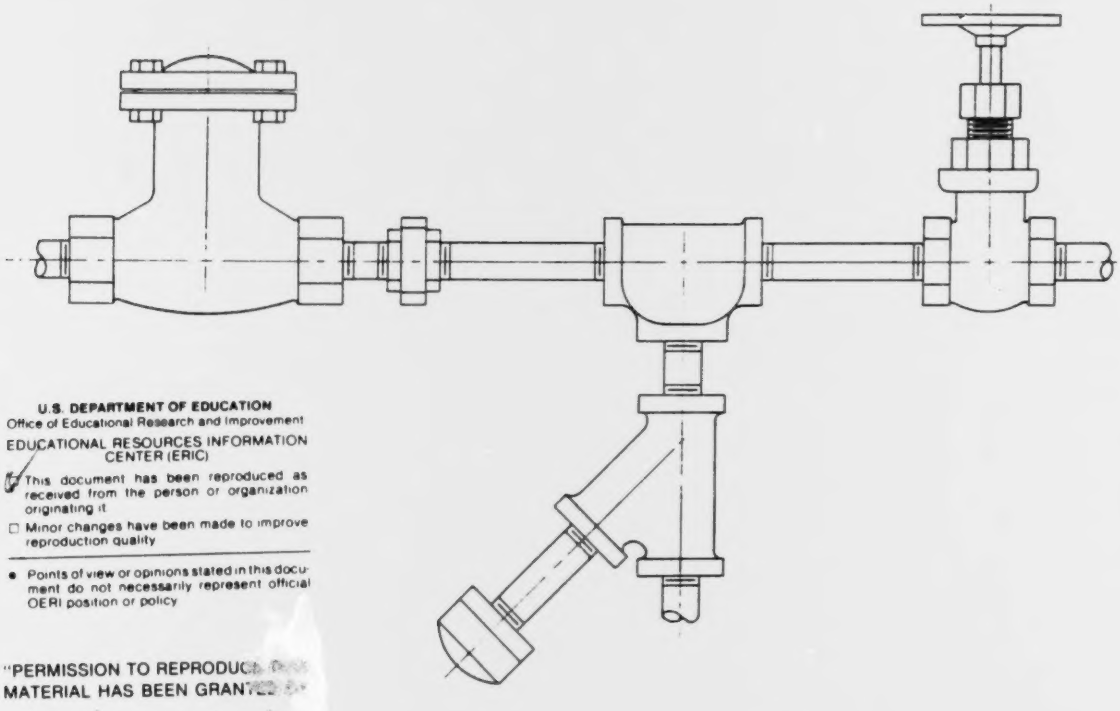
Wisconsin VTAE

Pipefitting Apprenticeship Curriculum



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Instructor Guide

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Foreword

A project was initiated in 1987 to develop related instructional material for the Industrial Pipefitter Apprentice Curriculum in the Wisconsin VTAE system. The project had three primary purposes: (1) develop a set of competencies or tasks for the pipefitting trade; (2) from the competencies, develop an instructor's curriculum guide; and, (3) from the competencies, develop an apprentice guide. A statewide ad hoc advisory committee composed of journeymen pipefitters and employer representatives was formed to provide input and feedback as the project progressed through its various phases.

The ad hoc advisory committee met at a two-day conference in 1988 under the direction of David Molnar (Special Projects Director/Applied Technology Education Center). The purpose of this conference was to define core topical areas and to identify relevant verbs to be used throughout the two-day meeting. As a result of the committees' work, competency statements were developed and a Business and Industry Questionnaire was created based on the statements.

Work on the second and third phases of the project began in the Fall of 1988. The Business and Industry Questionnaire was sent to approximately 50 businesses/individuals involved in the pipefitting trade. The questionnaire was used to validate and prioritize the curriculum content. Next, a meeting was called of the pipefitting instructors to review the competencies and the curriculum topics. As the curriculum was written, the ad hoc advisory committee met to review the curriculum content. As a result of this coordinated effort between industry and education, this guide was written. It is designed to provide uniformly high quality instruction to industrial pipefitter apprentices throughout the state. All involved in this project believe that this guide will allow apprentices to be well prepared and effective members of the pipefitting trade.

Paul Muhs, Curriculum Writer
Northeast Wisconsin Technical College
Green Bay, Wisconsin
June, 1989

Acknowledgements

A project of this size requires the input and talents of many individuals. Appreciation is extended to the Pipefitting instructors for their course materials and suggestions on texts and readings. Also, the input and time of the Pipefitter Apprenticeship Ad Hoc Committee was greatly appreciated.

Gratitude is expressed to the many corporations and manufacturers who provided pamphlets, technical bulletins, sales literature, and suggestions for this publication.

Thanks to Dave Molnar for making the transition between Phase 1 and 2 of the project a smooth one. Thanks also to Donna DeBauche and Pat Augustine for their editing and word processing work.

A special thanks to Roger Schauf for his "hands-off" management style and his constant encouragement.

Use of This Publication

This publication is designed to assist teachers in improving instruction and to assist apprentices in learning the pipefitting trade. Every effort has been made to make this publication readable and useable. As with all instructional material, however, revision is necessary. To assist in this process, a file is being maintained for changes or additions. If you find a typographical or spelling error or an area where clarification of content is necessary, send your recommendations for change to:

Associate Dean, Apprenticeship
Northeast Wisconsin Technical College
2740 W. Mason St.
P.O. Box 19042
Green Bay, WI 54307-9042

Instructional Units

Each instructional unit includes some or all of the following components: competencies, instructional objectives, learning activities, application exercises, evaluation/checkout, equipment, learning materials, audio-visual materials, and resources. Careful study of each instructional unit by the teacher will help determine the amount of material that can be covered in each class period, the skills that must be demonstrated, and the materials needed to develop these skills.

Competencies and Instructional Objectives

The competencies in each unit are a listing of the occupational or occupationally-related tasks to be addressed in that unit. The instructional objectives are stated in measurable terms which are steps toward mastering a competency. Instruction and evaluation are based on these objectives.

Learning Activities

In this section appropriate activities to help the apprentice master the instructional objectives are listed. This includes readings, videotapes, worksheets, and assignment sheets.

Application Exercises

The application exercises provide the apprentice with skill development experiences. The exercises are designed to be completed on-the-job. A list of the application exercises is provided in the Industrial Pipefitter Competency Profile which is included with this publication. If necessary, the instructor should demonstrate the skills that are required to accomplish the exercises.

Evaluation/Checkout

This section outlines how the apprentice's performance of the objectives will be evaluated. This includes a worksheet, assignment sheet, application exercises, and/or a test. In addition, a sample of test questions is included for each unit. The test should be used as a class-by-class evaluation of the objectives or as a final evaluation after the unit is completed.

Equipment

A listing of equipment and materials for the unit is mentioned in this section. For example, trainers and materials that would be useful in providing the apprentice with concrete examples would be listed here.

Learning Materials

A detailed listing of the materials that were mentioned in the Learning Activities section is provided here. A reference is given for each reading. A complete listing of all textbooks is given later in this introductory section. If an information sheet, assignment sheet, or worksheet is used, a copy of it is included with the unit. The information sheet is designed to provide material to supplement not duplicate the other readings. The assignment sheet and worksheet provide the apprentice with a study and/or practice activity to help him/her achieve the instructional objectives.

Audio-Visual Materials

When a videotape is used, a reference is given in this section. Before the videotape is used, it should be previewed by the instructor. Other than shipping and handling costs, most companies do not charge for this service. For a complete description of the videotapes, a catalog should be ordered from the companies. Addresses are given below for those companies whose videotapes were referenced frequently. Before a videotape is purchased, the VTAE library system should be checked for availability. Some of the material is available from manufacturers at no charge. See the Audio-Visual Materials section in each unit for more information.

NUS Training Corporation
9950 W. Lawrence Ave.
Suite 401
Schiller Park, IL 60176
(800) 678-3220
Contact Dorothy Burdziak

Industrial Training, Inc.
2023 Eastern Ave. S.E.
P.O. Box 7186
Grand Rapids, MI 49507
(800) 253-4623
Contact Ron Underwood

Tel-A-Train, Inc.
P.O. Box 4752
309 N. Market St.
Chattanooga, TN 37405
(800) 251-6018
Contact Evelyn Patterson

Video Training Resource, Inc.
7500 West 78th Street
Edina, MN 55435-2889
(800) 828-8190
Contact Thomas Linton

Marshall Maintenance Productions
529 S. Clinton Avenue
Trenton, NJ 08611
(800) 257-0430

L & K International Videotraining
295 Evans Ave.
P.O. Box 940
Station U.
Toronto, Ontario, Canada M8Z 5P9
(800) 668-6064
Contact Maxine Jelilyan

Industrial Training Corporation
13515 Dulles Technology Drive
Herndon, VA 22070
(800) 638-3757
Contact Edwin Winder

ASTD Training Video Directory
American Society for Training
and Development
1630 Duke St.
P.O. Box 1443
Alexandria, VA 22313
(703) 683-8100
Request the Technical and Skill
Training Programs Directory.

Resources

This section provides the instructor with supplemental material, such as books, pamphlets, and audio-visual material.

Competencies

1. Describe fundamental communication skills and how they influence work in the trade.
2. Demonstrate safe practices necessary in the trade.
3. Recognize safe use of tools and equipment used in the trade.
4. Identify proper procedures and potential problems of ladder and scaffold use.
5. Recognize equipment and clothing used to protect against hazards in the work environment.
6. Demonstrate safe practices for the use of common power tools used in the trade.
7. Demonstrate the use of the methods of measurement used in the trade.
8. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
9. Demonstrate the ability to clean, flux, and soft solder a joint.
10. Demonstrate the ability to silver braze joints and silver braze a copper to a steel joint.
11. Demonstrate general safe practices for handling chemicals.
12. Demonstrate the ability to withdraw chlorine and/or caustic soda from containers.
13. Describe various types of hot water heating systems.
14. Identify types of boilers and appropriate safety devices for hot water heating systems.
15. Explain venting and piping considerations for hot water heating systems.
16. Demonstrate the ability to maintain a hot water heating system.
17. Explain the basic principles involved in hydraulic system operation.
18. Describe the advantages and disadvantages of a hydraulic system.
19. Summarize safety practices for working on hydraulic systems.
20. Explain how the principles of pressure and flow are used in hydraulic systems.
21. Identify hydraulic system symbols.
22. Describe the purpose and characteristics of hydraulic fluid.
23. Explain how reservoirs and filters are used in a hydraulic system.
24. Identify components of reservoirs and filters.
25. Demonstrate the ability to clean and inspect a reservoir.
26. Demonstrate the types of pipe/tubing and fittings used to carry hydraulic fluids.
27. Describe the types of seals and seal materials required for hydraulic application.
28. Explain how leaks can be prevented in hydraulic systems.
29. Demonstrate the ability to work with pipe/tubing/hose used in hydraulic systems.
30. Demonstrate the ability to install seals for hydraulic components.
31. Explain the purpose of hydraulic actuators and identify the different types.
32. Indicate how a hydraulic actuator is chosen for a particular application.

33. Demonstrate the ability to repair a hydraulic cylinder.
34. Explain the function and operation of directional controls, pressure controls, and volume controls in a hydraulic system.
35. Determine what type of control is necessary for a particular application.
36. Demonstrate the ability to repair/install hydraulic controls.
37. Explain the function and operation of the various types of pumps used in a hydraulic system.
38. Perform various calculations concerning pump operation.
39. Demonstrate the ability to repair/install hydraulic pumps.
40. Describe the purpose and operation of accumulators, coolers, heaters, and intensifiers used in a hydraulic system.
41. Identify measurement instruments used in a hydraulic system.
42. Describe the components of a basic hydraulic circuit.
43. Identify the symbols used in a hydraulic circuit.
44. Identify applications of hydraulic circuits.
45. Draw hydraulic circuits.
46. Demonstrate the ability to troubleshoot and maintain hydraulic systems.
47. Demonstrate the ability to diagnose and test hydraulic systems.
48. Evaluate different types of insulation that are used in the pipe-fitting trade.
49. Demonstrate the ability to repair and install insulation.
50. Perform calculations in basic arithmetic.
51. Perform calculations in basic geometry.
52. Perform calculations in basic algebra.
53. Perform calculations using right triangles.
54. Perform calculations in trigonometry and generalize their solutions to the trade.
55. Interpret basic electricity theory and practice as it relates to troubleshooting, repair, and maintenance.
56. Describe energy and its relationship to work, power, and efficiency.
57. Identify the states of matter.
58. Define the properties of solids, liquids, and gases, and perform work related calculations dealing with these properties.
59. Interpret the relationship among temperature, heat, and expansion.
60. Describe heat transfer.
61. Explain change of state.
62. Describe how heat influences change of state.
63. Demonstrate the use of steam tables.
64. Describe the purpose of hangers and supports in piping systems.
65. Demonstrate the ability to install/fabricate hanger and support setups.
66. Differentiate between categories of pipe welding.
67. Identify pipe welding qualification positions.
68. Describe safety requirements for pipe welding.
69. Demonstrate equipment required for pipe welding setup.
70. Demonstrate the ability to use welding setup equipment.
71. Discuss the use of pipe symbols in blueprint reading and layout for pipe welding.
72. Identify symbols for pipe and pipe fittings.
73. Describe the advantages of using isometric drawings for pipe

welding blueprints.

74. Solve basic layout problems.
75. Construct templates for pipe welding applications.
76. Identify proper electrodes for pipe welding.
77. Describe joint preparation, fit-up, alignment, and cleaning requirements for pipe welding.
78. Explain methods of nondestructive and destructive weld testing.
79. Demonstrate the ability to bevel and prepare pipe for welding.
80. Conduct destructive tests on welded pipe.
81. Weld to specifications V-groove joints in vertical up and vertical down positions.
82. Demonstrate the setup, use, and care of oxyacetylene welding-cutting equipment.
83. Demonstrate the setup, use, and care of shielded metal arc welding equipment.
84. Describe the manner in which a force is transmitted through a confined fluid.
85. Explain the operation of transmitting energy in an efficient pneumatic system.
86. Distinguish among the various control devices used in a pneumatic system.
87. Describe the operation of and be able to identify the compressors of typical pneumatic systems.
88. Explain the purpose of aftercoolers, driers, and receivers in a pneumatic system.
89. Describe typical piping systems for a pneumatic system.
90. Demonstrate the ability to inspect a pneumatic system for leaks.
91. Demonstrate the ability to install a drain trap in a pneumatic system.
92. Identify check valves, cylinders, and motors and describe their basic operation and typical application.
93. Demonstrate the ability to repair/install a pneumatic cylinder.
94. Identify pneumatic directional control valves.
95. Describe the operation of pneumatic directional control valves.
96. Explain the basic functions, operation, and placement of flow control valves, silencers, and quick exhaust valves.
97. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve in a pneumatic system.
98. Explain the function of regulators, excess flow valves, boosters, and sequence valves that are found in a typical pneumatic system.
99. Describe the components of air preparation, their operation, and the sources of contamination for a pneumatic system.
100. Demonstrate the ability to repair/install a pressure regulator in a pneumatic system.
101. Demonstrate the ability to repair/install an air line filter in a pneumatic system.
102. Demonstrate the ability to repair/install a lubricator in a pneumatic system.
103. Demonstrate the ability to repair/install a FRL unit in a pneumatic system.
104. Identify and use basic drafting tools.
105. Draw freehand sketches.

106. Demonstrate basic drafting techniques.
107. Create multi-view drawings.
108. Describe pipe and pipe fittings in terms of pipe drafting.
109. Explain how valves and measurement instruments are shown in pipe drafting.
110. Explain how pumps, tanks and piping equipment are shown in pipe drafting.
111. Create multi-view drawings of pipe and fitting assemblies.
112. Interpret drawings of pipe and fitting assemblies.
113. Describe the purpose of a flow diagram.
114. Explain the parts of a flow diagram.
115. Describe the purpose of elevation drawings and section drawings.
116. Describe the components of a piping plan.
117. Interpret the information on flow diagrams, elevation drawings, section drawings, and piping plans.
118. Define what an isometric drawing is.
119. Describe the layout of an isometric drawing.
120. Sketch isometric piping and fittings.
121. Explain the purpose and layout of a spool drawing.
122. Read a specifications book and develop a material list for a specific job.
123. Explain stress in relation to piping material.
124. Evaluate strength of piping material.
125. Interpret expansion/contraction effects.
126. Describe characteristics and applications of piping materials.
127. Describe types of joints and bonding techniques for piping materials.
128. Interpret flow properties of piping materials.
129. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe bends, linear expansion of piping, volume of tanks, and offsets.
130. Fabricate piping offsets.
131. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe welding layouts including miter cuts, cut lines on large pipe, tees, saddles, laterals, and elbows.
132. Use clamps and aligning devices employed in the trade.
133. Fabricate miters, tees, saddles, laterals, and elbows.
134. Describe the types of and operation of watertube and firetube boilers.
135. Explain the four separate systems that must function in order for a steam boiler to operate.
136. Explain the purpose of the steam boiler fittings that are required to operate the boiler safely and efficiently.
137. Describe the steam boiler accessories that are necessary for its safe and efficient operation.
138. Demonstrate the ability to install steam boiler fittings and accessories.
139. Describe the types of and purposes for the steam and water devices which are necessary for the boiler's efficient operation.
140. Identify the instruments that are used to control and measure boiler operation.
141. Explain the function of the auxiliary equipment which is part of the steam power plant operation.

142. Demonstrate the ability to install feed water devices.
143. Explain how steam heating systems work.
144. Describe the various types of steam heating systems.
145. Describe the function of the fittings and accessories used on a steam heating system.
146. Repair and maintain steam heating systems.
147. Define steam trapping terminology.
148. Identify applications for steam traps including location, installation and sizing.
149. Demonstrate the ability to repair and install steam traps.
150. Describe the basic thermodynamics of refrigeration.
151. Define and identify components of the basic mechanical refrigeration cycle.
152. Identify basic components of an air conditioning system.
153. Identify safe practices associated with refrigeration and air conditioning systems.
154. Identify special tools used on air conditioning and refrigeration equipment.
155. Explain the purpose of common refrigeration system accessories.
156. Demonstrate the ability to install common refrigeration accessories.
157. Describe the purpose of a refrigerant in a refrigeration system.
158. Explain the relationship between temperature and pressure in a refrigeration system.
159. Demonstrate use of the vacuum steam table.
160. Demonstrate the ability to evacuate a refrigeration system.
161. Distinguish between different types of tubing and fittings used in air conditioning and refrigeration installation/maintenance.
162. Identify the proper size and type of tubing and fittings needed for particular air conditioning and refrigeration jobs.
163. Demonstrate the ability to flare, bend, and swage tubing.
164. Identify different piping materials and pipe fittings used in air conditioning and refrigeration installation/maintenance.
165. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
166. Demonstrate the ability to clean, flux, and soft solder a swage joint.
167. Demonstrate the ability to silver braze swage joints and silver braze a copper to a steel joint.
168. Demonstrate the ability to pressurize a refrigeration system with dry nitrogen.
169. Demonstrate the ability to use soap bubbles, a halide torch, and an electronic leak detector to find a refrigerant leak.
170. Demonstrate the ability to vapor charge and liquid charge a refrigerant system.
171. Demonstrate basic safe practices associated with rigging.
172. Design templets and develop patterns into models.
173. Fabricate pipe intersections through the use of templets.
174. Identify piping system valve types and applications.
175. Describe and use different types of packings and gasket materials by appropriate application.
176. Demonstrate the ability to repair/install valves.

Textbooks

1. Air Conditioning Clinic. La Crosse, Wisconsin: Trane Company Educational Department, 1978.
2. Basic Industrial Mathematics: A Text Workbook. New York: Mc Graw-Hill Book Company, 1972.
3. Bowman, S. Ordinates for 1000 Pipe Intersections. Baton Rouge, Louisiana: Claitor's Publishing Company, 1977.
4. Brumbaugh, J. Heating, Ventilating, and Air Conditioning Library-Volume I. New York: MacMillian Publishing Company, 1986.
5. Chlorine and Caustic Soda. Pittsburgh, Pennsylvania: PPG Industries, 1986.
6. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986.
7. Fortney, C. and Gregory, M. Shielded Metal Arc Pipe Welding. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984.
8. Frankland, T. The Pipefitter's and Pipe Welder's Handbook. Mission Hills, California: Glencoe Publishing Company, 1984.
9. Hewitt, Paul. Conceptual Physics, 6th Edition. Glenview, Illinois: Scott Foresman, 1989.
10. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
11. Industrial Pneumatic Technology. Cleveland, Ohio: Parker Hannifin Corporation, 1980.
12. Jones, R. Templet Development for the Pipe Trades. Albany, New York: Delmar Publishers, 1966.
13. Know Your Hoses, Tubing, and Fittings. Cleveland, Ohio: Penton Publishing Company, 1983.
14. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
15. Newberry, W.G. Handbook for Riggers. Calgary, Alberta: Newberry Investments Company, Ltd., 1977.
16. Principles of Arc Welding. Appleton, Wisconsin: Miller Electric Manufacturing Company, 1980.
17. Quinlan, C. Orthographic Projection Simplified. Mission Hills, California: Glencoe Publishing Company, 1987.

18. Shumaker, T. Process Pipe Drafting. South Holland, Illinois: Goodheart-Willcox Company, Inc., 1985.

19. Steingress, F. and Frost, H. High Pressure Boilers. Homewood, Illinois: American Technical Publishers, 1986.

20. Wantiez, G. Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984.

21. What a Journeyman Should Know About Electricity. Falls Church, Virginia: National Association of Plumbing, Heating, and Cooling Contractors, 1985.

This is a list of the text reading material for the course. For other instructional material, the teacher should review the Learning Materials section in each unit.

Approximate Times for Each Unit

Introduction to the Trade I-V	8-10 hours
Brazing and Soldering	8-16 hours
Chemical Handling	15-20 hours
Hot Water Heating Systems	15-20 hours
Hydraulics I-VIII	75-90 hours
Insulation	8-12 hours
Mathematics I-IV	35-45 hours
Physics I-V	75-85 hours
Pipe Hangers and Supports	8-12 hours
Pipe Welding I-III	30-60 hours
Pneumatics I-V	25-35 hours
Process Pipe Drafting I-IV	40-45 hours
Process Piping Fabrication I-IV	50-70 hours
Process Steam Systems I-V	70-80 hours
Refrigeration and Air Conditioning I-VI	30-60 hours
Rigging	8-12 hours
Templet Development I-II	30-60 hours
Valves, Packings, and Gaskets	8-12 hours

Competency:

1. Describe fundamental communication skills and how they influence work in the trade.

Instructional Objectives:

1. Identify elements of a communication.
2. Describe types of non-verbal communication.
3. Define feedback.
4. Describe factors that frequently contribute to poor listening and understanding.
5. Identify procedures for improving listening skills.
6. Describe techniques for asking questions.

Learning Activities:

1. Read Chapters 2, 3, and 4 in Interpersonal Skills and Communication - Apprenticeship Related Instruction.
2. Complete the Self-Test Exercises at the end of each chapter.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. Rice, E. and Hughes, J., Interpersonal Skills and Communication - Apprenticeship Related Instruction. Raleigh, North Carolina: Conserva, Inc., 1982. A copy of chapters 2, 3, and 4 is included with this unit.
2. A copy of the self-test exercises and answers and a copy of the test and answers is included with this unit.

2. Communication Requirements and Components

Introduction and Objectives

Thoughts, ideas, feelings and understandings are individual or personal experiences. To share these events, you must communicate with another person. The most frequent form of communication for human beings is speech. Using words, as well as gestures and expressions, people are able to explore, express, test and share meaning. Such sharing is possible *if* the people involved in the communication use words, gestures, and expressions in a way that accurately conveys meaning and if the people involved in the conversation attend to what each is trying to convey to the other. This two-way type of communication is critical. Each party in the communication must work to clarify, present and understand individual communications.

This chapter is about elements within the process of interpersonal communication. It addresses several of the more important components in the communication process including non-verbal communication, feedback, and verbal communication. When you have completed your work in this unit, you will demonstrate your understanding by being able to:

1. Identify elements of a communication:
2. Critique and clarify samples of individual communications in the work setting;
3. Critique communication and provide feedback; and
4. Interpret and respond to non-verbal communication.

Principles, Examples and Applications

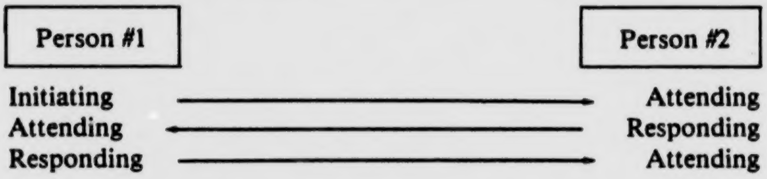
The Communication Process

Suppose as an apprentice, you are working at your station when another apprentice on the floor who has been working on a different machine walks into your area. With an irritated scowl on his face, he curses and complains about having been "ordered by the foreman to stop working on the press and to sweep up this area." You remember that recently the apprentice had been moved from clean-up duty to working on the new printing press and was excited about finally learning some skills with the machines. Further, the trainee had been looking forward to working on the large, rush printing order the shop had received for that week. Suddenly and without explanation he had been taken off the job before it even began. He picked up the push broom and began sweeping, but he was not happy about it. No one spoke to him.

Three basic points are important in this situation. First, people tend to react to the *way* something is said and to what is *not said* rather than to *what* is said. The foreman, overhearing the apprentice's complaint, may tell him to shut up and stop complaining and completely miss the fact that the apprentice is disappointed and confused. Second, what people say and how they say it usually is based on the way people feel. Feelings influence behavior and particularly communication. Understanding feelings is essential to interpreting a communication. The apprentice was angry at having been given no explanation for why he had been "demoted" to clean-up detail. Further, he was disappointed about not getting to work and contribute on an important job for the company. The person speaking needed to realize that feelings affect communication. If a speaker is aware of feelings then he or she can say what is meant. Third, for there to be meaningful communication, people must share meaning. They must speak with one another and engage in the process of (a) initiating communication, (b) attending to communication and (c) responding in communication.

The communication process is illustrated in Figure 1. The arrows indicate the direction of the flow of communication.

Figure 1: The Communication Process



Initiating

The first part of the communication process is termed initating. It refers to the process of speaking and gesturing to someone else in order to begin a conversation or communication. It involves (a) deciding what you want to say; (b) making the other conversants aware (or getting their attention) of your desire and intention to communicate; and (c) offering your comments. In deciding what you want to say, you must decide on both the purpose and the intent of your comment or question. Your purpose is the "why" of your comment and your intent is "what" you hope to achieve. Remember, your feelings and your reason influence both what you want to say and how you want to say it.

Getting the attention of the other conversants is the second task in the initiation process. Sometimes the speaker does this by simply appearing on the scene, sometimes by gesturing, and sometimes with his or her voice. In the example of the upset apprentice in the print shop, he got the attention of everyone else by coming into the room and by raising his voice in anger. In other instances, whispers, questions, shouts or simply speaking may be sufficent for getting attention.

The third part of the initiating process is offering your comment. As an initiator, you offer words and gestures to indicate what you mean. Again, remember that not only what you say, but also (a) how you say it, (b) the gestures you use, and (c) what you do not say are as important as what you say. Ideas about ways to speak effectively are included elsewhere in this chapter.

Attending

The process of attending to the communication of the initiator in a conversation involves paying attention, listening, observing, and thinking about what is being said. This process involves avoiding having objects such as desks between you and the person speaking, watching for non-verbal clues to the meaning of the message being spoken, listening to the words spoken and unspoken, establishing and maintaining eye contact with the speaker, and considering both what is said and the way it is said. Do not forget to take the feeling (emotion) of the speaker into account as you think about the meaning of the communication.

The process of attending is absolutely critical. It is the way you come to understand. It is so important that other parts of this chapter are devoted to non-verbal communication. A whole chapter is devoted to listening, the most critical part of the attending process.

Responding

The third part of the communication process is responding. It includes considering what the other person has said; capturing the gist of what was said and certifying that your understanding is correct; using words that show that you understand the message spoken; formulating your response; and delivering your response. Responding encompasses all the elements of initiating except that awareness/attention has been established because the speaker offered an original comment to which the respondent replied. Further, responding has the added responsiblity of requiring the responding conversant to use the initial comment as the basis for his or her own comment. The anticedent comment must serve as the stimulus and background for the responding comment in order for meaning to be shared.

Factors That Influence Communication

Communication is a two-way process that involves both the sender and receiver of information in working with the words and gestures that constitute the message sent and received. A number of factors influence the effectiveness of communications. Among the more important factors are those of self, attitude/outlook, and language.

Self

Your experience as a communicator influences your ability to communicate effectively. If you lack self-confidence or experience, you may hestiate to engage in conversation or may be reluctant to ask clarifying questions. This may result in little personal growth in either self-confidence or experience.

Figure 2 is a communication skills survey that will help you to consider your strengths and limitations related to communication situations. Take a few minutes and complete the survey by checking the appropriate column. Answer honestly and remember that there are no right or wrong answers.

Figure 2: Communication Survey

Item	YES (Usually-Always)	NO (Seldom-Never)
1. Is is difficult for you to talk with other people?		
2. Is it difficult for you to accept criticism?		
3. Does it seem that people usually are interested in what you have to say?		
4. If you do not understand something that someone has said, do you ask the speaker to explain the comment or directions?		
5. Do you think that people usually understand your comments without attitional explanation?		
6. Do the words you speak usually come out the way you want them to?		
7. Do you pay attention when other people are talking? (Don you catch yourself not paying attention?)		
8. In conversations, do you talk more than the other people?		
9. When talking, do you allow the other person to finish speaking before you begin.		
10. Do you agree or disagree with others because of concern about how they will feel about you?		

Adapted from: R.E. Nelsen. *Occupational Survival Skills.* Urbana, Illinois: University of Illinois at Urbana-Champaign; 1979.

Look back over your answers. If you answered any of the questions in the following way, you have identified areas where you may need to work.

	Probably O.K.	**Probably Needs Work**
#1	No	Yes
#2	No	Yes
#3	Yes	No
#4	Yes	No
#5	Yes	No
#6	Yes	No
#7	Yes	No
#8	No	Yes
#9	Yes	No
#10	No	Yes

Self-concept and self-image are directly affected by communication skills because everyone is aware of how other people respond to what they say. It is important because the way you present yourself in words and actions has a great deal to do with how well the words you are speaking are accepted.

Attitude and Outlook

Communicating with words and gestures creates problems of misunderstanding because words are, at best, symbols. Their meanings change as the context in which they are spoken change. Further, words sometimes mean different things to different people. Problems occur when the speaker and listener assume that the way each individual uses a word is exactly the way the other also uses a word. The result can be confusion because there can be no shared meaning if there is no agreement about the meaning of words between the sender and the receiver of a message.

The problem of context is further complicated by the attitudes of the people engaged in the conversation. For example, people hear what they expect and want to hear. Past experience and current needs or wants condition everyone to listen, see and read selectively. As a result, sometimes the people to whom you speak miss completely the point you are making even though you have spoken carefully. Likewise, sometimes the listener will focus on a relatively minor part of the message that was related to the listener's past experience while missing the primary point of the message. In similar fashion, being cold, hot, hungry, tired, bored, angry, excited, or nervous can cause the listener to focus on only a small part of a message and to miss the major ideas.

Another compounding problem associated with the influence of attitudes and situations on understanding meaning is the tendency of everyone to evaluate the message they receive. It is only natural for a listener to hear a speaker and to decide if he or she agrees or disagrees with what is said from his or her own point of view. Often listeners consider messages in terms of right-wrong, good-bad, reasonable-illogical and so forth without regard to the possiblity that the message may either not need to be evaluated *or* may be both good and bad or somewhere between reasonable and illogical. Remember, to evaluate means to place, to compare and to value what is said in terms of your own values. Only after understanding the facts can you place a value on what is said.

Language

The meaning of words depends on the context in which they are used as well as the past experience of the people who are using the words. Remember, there is no communication if the persons engaged in the conversation do not agree on the meaning of the words. Words are simply tools for conveying meaning in communication in the same way that saws and hammers are the tools for building a house. As with saws and hammers, you must practice using words in order to become a skillful user of the tools. Practice comes from reading, from writing, from speaking and from thinking. Additional practice comes from avoiding problems that arise in language use. These problems include:

Use of Jargon. Every group of friends and workers develops its own special language or its own special words with particular meanings. This is especially true in the skilled trades where one of the important tasks is to learn the terms, slang and jargon of the trade. Remember, persons outside your trade and/or your group of friends may not understand the particular meaning you have for certain words. Likewise, you may know the exact meaning other people apply to particular words.

Emotional Words. Words convey emotion. Sometimes for very unusual reasons a simple word like union or management or conservative or liberal can convey a message that was not intended by the speaker. In such instances, the listener heard only what he/she consciously or unconsciously wanted to hear because of past experiences and the emotions associated with those experiences.

Assuming Too Much. Everyone assumes too often that the person to whom they are speaking (or writing) knows more about the message being sent than they actually do. Who has not been in a conversation in which they did not know what the speaker was saying even though the speaker believed they did. Always assume the person with whom you are speaking *does not know* what you are talking about unless they tell you otherwise.

Non-Verbal Communication

People communicate not only through words, but also through gestures, eye contact, facial expressions, and posture. In fact, people learn to communicate through gestures months before they learn to speak and years before they learn to write. It is a skill used throughout life. Non-verbal communication facilitates both speaking and listening. Findings from a number of research studies suggest that perhaps as much as 70 percent of any face-to-face message is conveyed non-verbally. This means that the tone of your voice and the look in your eyes are at least as important as what you say. Further, when words and gestures are used together, they greatly reinforce the spoken communication. For example, say you see a long-time acquaintance whom you have not seen in some time. You say, "I'm really glad to see you!" Obviously, you are conveying a message, but image how much stronger that message would be if your words were accompanied by a firm handshake, an embrace, a smile, a hearty and excited voice tone, or emphasis on the word "really'. In this latter instance, gestures and words support and reinforce one another.

There are three major types of non-verbal communication of concern: (1) consistency, (2) voice tone, and (3) eye contact and posture. Each is a tool for effective communication.

Consistency

Remember that actions speak at least as loudly and as eloquently as words. If you say something like "Nice job" to another worker, but do so in an insincere tone of voice, or without pause in the context of another conversation, or without really paying attention to the product of the work, you will generate confusion. Your words will have said one thing but your actions will have said something else. Remember, when a contradition occurs between verbal communication and non-verbal communication, usually the non-verbal message will prevail. Actions are more eloquent than words.

Voice Tone

The sound of your voice usually reflects your innermost feelings. Factors of concern include pitch, quality/volume and rate/rhythm. Of particular concern is pitch or the relative highness or lowness of your voice. Lower pitches usually mean relatively little enthusiasm or interest while a relatively high pitch means excitement. Usually a varied pitch indicates interest in the topic under consideration and a concern of the speaker.

Quality and volume are factors in reinforcing the messages of words. Through varying the volume, you can emphasize certain ides, phrases, or words. Voice clarity indicates the emotional state of the speaker; for example, often if you are tense or unsure, your voice will sound unsteady and unsure.

Rate/rhythm also indicate to the person to whom you are speaking something about how you feel. Rapid delivery of comments from a speaker may mean that the conversation is inconvenient or not perceived to be necessary. Faster rates coupled with short, tense comments frequently signal irritation. Long comments, slow rates, and few pauses may signal indecision while frequent pauses may signal indecision, tension or resistance. And silence...remember that silence is eloquent. It can signal anger, interest, boredom, confusion, agreement or any of a number of things. Always view silence in the context of whatever else is going on.

Eye Contact and Posture

Eye contact may convey more information than any other means of communication. Who has not been silenced by a withering look from a spouse, supervisor, friend, or parent? Remember that eye contact is a two-way exchange of information. The speaker "feels" your attention; conversely, you can get a better understanding of what the speaker is saying by observing facial expressions and eye movement. It is virtually an unwritten rule of communication in this society that when you talk with someone, you look at them and they look at you. Likewise, if you look at someone, most peple feel they should talk.

By establishing and maintaining eye contact, the speaker is signaling interest in expressing and having a point understood. Likewise, establishing and maintaining eye contact frequently is an expression of confidence and sincerity. Note, however, that eye contact and staring are not the same thing and that staring often is considered rude and makes the person who you are looking at feel uncomfortable.

Posture is another critical non-verbal cue in communication. If you are engaged in communication, how you sit affects the speaker. If, for example, you are being spoken with and you slump back in your chair, you tend to indicate disinterest or resistance. Instead, if you sit comfortably, relaxed and slightly inclined toward the speaker, you indicate interest. Not only does this make the speaker understand that you are supporting and listening, it also tends to make you feel like you should be listening.

Exercises

By way of review of information about non-verbal communication, answer the following questions:

1. A supervisor explained that a certain work procedure was to be done in a prescribed manner, following steps a, b, c, and d. Later, however, you observed the supervisor and several journeymen doing the job using the steps in the sequence of a, d, c, b rather than a, b, c, d. What communication would you most likely believe and why?

Answer: Which communication? ______________________________

Why? ______________________________

2. How does eye contact affect both the speaker and the listener?

Answer: Speaker ______________________________

Listener: ______________________ ____________

3. Spend 15 minutes observing communication around you. Note the (a) posture, (b) eye contact, (c) gestures, (d) voice tone, and (e) consistency of the participants. What does your observation tll you about the communication?

Answers:

1. Which? - a, d, c, b Why? Actions speak louder than words.
2. Speaker - eye contact from listeners indicates attention, interest and support; Listener -eye contact from speaker indicates sincerity, directness and interest.

Ways of Improving the Two-Way Communication Process

There are several direct ways of improving the two-way communication process including using feedback and developing effective speaking/writing techniques. Each is discussed in turn below.

Feedback

Effective communication requires practice at giving the speaker clear indictions of how much of the message you understand as well as practice at receiving such indications from the person to whom you are speaking. This process is called giving and receiving feedback. It has a great deal to do with how well people perform in carrying out assignments. Only if you understand what is expected of you can you do a good job.

The rules and guidelines for feedback are as follows:

1. Focus feedback on description rather than judgement—in offering feedback, concentrate on "what" is happening rather than "why" something is happening. The "what" is usually observable whereas the "why" frequently is a guess on your part. In addition, the "what" usually can be described, discussed and reassessed if necessary. Further, by clarifying the "what" you learn exactly what behaviors are expected. Avoid overloading description with too many details but always try to include examples.

2. Focus feedback on observable behaviors rather than on personality or inferences—observations and behavior are events that can be seen and/or heard by everyone whereas inferences are guesses about what is going on, or why. Observable feedback deals with what is going on at the moment or has recently been completed. It rarely deals with events in the distant past. The currency of feedback makes it more useful and easier to concentrate on. Further, by focusing on events and avoiding judgements of personality and guesses about motives, you remove the tendency of the person with whom you are speaking to be defensive. In dealing with observable behavior, remember you can deal with all aspects of activity. Also, remember, nothing is absolute; rather, things exist in degrees. Concentrate feedback both on things that are done correctly and things that need improvement.

3. Focus feedback on needs of the person to whom it is offered—consider what can be done with the feedback you offer. If it is only likely to satisfy your need to say it, you may not be helping much by offering the feedback. Consider the information needs and emotional state of the person to whom you are speaking. Correct mistakes and offer criticism, but do it in a constructive fashion. Do not use feedback to condemn or threaten another person. Also avoid offering feedback in situations where the person to whom you are speaking has no chance of correcting the action or message, even with good feedback.

In addition to these general guidelines, rmember several other ideas when giving feedback. First, it is a good idea to make a habit of giving and seeking out feedback. This practice will improve your communication skills while improving the possibility that the messages you send and receive are understood. Know that while you may feel awkward doing this at first, your skills will improve with practice as will your abilities to speak, listen and question.

Second, when you are providing feedback, try to provide positive statements, especially if part of the feedback is negative. In addition, be honest and tell people what you think they mean. Further, use an economy of words in order to focus on relatively few ideas, comments or facts.

Third, if the feedback you have offered brings no improvement or change from the other person, do not repeat the feedback. Try some other feedback if you believe it to be warranted, but do not waste your own time if the other person will not listen. Do not threaten the other person if the other person cannot listen.

Effective Speaking/Writing Techniques

As a speaker or writer, there are several things you can do to improve the probability that your communication will be understood correctly. Each of several techniques is noted and discussed below.

Consider and Organize Information. Before speaking (or writing), consider what you want to say in terms of what you want to accomplish with your comments and the order in which you want to make your points. If you know what you want to say and why, your comments will be brief, more concise and more accurate. It is particularly important to organize your facts and ideas if you are arguing a point or trying to persuade someone of something.

Consider Your Audience. To whom are you speaking? Knowing your audience is almost as important as what you will say. Be sure you are saying or writing information of interest, concern or need to the intended audience. Further, speak or write using words familiar to the person or persons with whom you are communicating.

Use Examples. As you offer suggestions, present ideas/concepts or try to make points, offer examples that will help the person(s) with whom you are communicating to understand what you are saying. Draw examples from the experience of the audience because they provide immediate insight. Examples demonstrate both what you are talking about as well as cases that do not apply.

Avoid Distractions. As you speak or write, avoid distractions. Stick to the main points. Avoid being side-tracked and do not introduce confusing ideas. Avoid distracting non-verbal mannerisms and gestures. Make your non-verbal cues reinforce the words you are speaking. Use eye contact and voice emphasis. Avoid impulsive mannerisms like cracking your knuckles or drumming your fingers.

Ask Questions. After you have spoken, ask questions to the person(s) with whom you spoke to see if they understood what you said. Focus first on your overall aim or idea to be sure it was understood before asking about specific facts or ideas. When you are the listener, ask clarifying questions and explain to people what you think they mean. Phrase the questions positively to avoid making the person to whom you direct the question defensive.

Exercises

Check your understanding of communication as a two-way process by answering the following questions.

1. How are the emotions and attitudes of the people involved in a communication important? Answer: ____________________

2. Why should seeking out and giving feedback become a habit? Answer: ____________________

3. What kinds of distractions must you avoid when communicating with someone else? Answer: ____________________

Answers

1. People speak and listen selectively based on past experience, and attitudes. Some words cause immediate reactions.

2. It improves speaking and listening, both for speaker and listener. It insures understanding and sharpens skills.

3. Providing unrelated information; sending confusing verbal and non-verbal messages; using nervous, attention-robbing gestures.

Additional Information

For additional information you might read:

J. W. Keltner, *Elements of Interpersonal Communication* Belmont, California: Wadsworth Publishing Co., Inc., 1973.

R. E. Nelson. *Occupational Survival Skills.* Urbana, Illinois: University of Illinois at Urbana-Champaign; 1978.

Self-Test Exercises

Answer the following questions about effective communication. Compare your answers with those suggested in the Appendix of this booklet. If you answer 70% of the items correctly continue work in the next chapter. If you score less than 70%, reopen your work in Chapter 2.

1. Attending to the trainee means physically attending, observing and ____________ to the trainee.

2. What three major tasks are involved with initiating a conversation?
   Answers: a. ____________________
   b. ____________________
   c. ____________________

3. If your words and your actions are contradictory, which is the listener likely to believe? Answer: ____________________

4. Which of the following non-verbal types of communication conveys the most information?
   - a. voice tone
   - b. eye contact
   - c. hand gestures
   - d. posture

5. How is jargon a language problem in spoken and written communication?
   Answer:______________________________

6. Why should feedback focus on description of behavior?
   Answer: ______________________________

7. What techniques are available for helping you to communicate more effectively with an audience?
   Answer:______________________________

3. Listening

Introduction And Objectives

Imagine that you are talking with five people when two of them walk away, the third turns to the fourth to speak privately and the fifth responds to your comment with a question that is totally unrelated to what you were saying. Certainly the behavior of the people with whom you were speaking is rude. Just as sure, however, will be your own discomfort and anger, as you realize that no one was listening.

In truth, everyone is guilty of poor listening at some time. Even though as much as 90 percent of all communication is verbal, the average listener remembers only about half of what he or she hears immediately after hearing the information. Within a few hours, only 20 percent to 25 percent of what unconsciously ignore whatever the speaker is saying. Likewise, a listener may decide unconsciously to ing effectiveness decreases as the number of people engaged in the conversation increases. Listening effectiveness also decreases with age. Ineffective listening due to advancing age and increasing numbers of people in the conversation most often is attributable to inattention or preoccupation.

Listening is a natural process. Usually it is taken for granted by individuals and ignored in instructional settings, even when the instructional content is interpersonal communication. Nevertheless, listening involves a specific set of communication skills that can be improved through instruction and practice. The instructional materials in this chapter are focused on improving listening skills. When you have completed your work in this unit, you will demonstrate your competence by being able to:

1. Describe factors that frequently contribute to poor listening and understanding;
2. Suggest procedures for improving listening skills; and
3. Critique conversations and situations to point out potential problems.

Principles, Examples and Applications

Factors Involved with Ineffective Listening

Many factors contribute to ineffective listening. Distractions, emotions, prior learning and prejudging each can contribute to missing critical information during a conversation. Even the listener's own ability to process information can contribute to poor listening habits. More specifically, the average person can talk at a rate of about 125 words per minute; however, the average mind can process about 600 to 800 words per minute. As a result, an individual listener in a conversation is left with "time" to think about other things, "time" to formulate a response for the conversation or "time" to consider carefully the facts and implications of that which is being said.

If several people are involved in the conversation, the listener is left with even more "time". In fact, the larger the number of people involved in a conversation, the greater amount of time any one person spends listening. If just two people are having a conversation, each probably will be talking and listening about 50 percent of the time. If four people are engaged in conversation, each will be listening about 75 percent of the time. This means that not only is there more time for listening, but also there are more opportunities for distraction. As a result, the need to listen carefully increases proportionately as the number of people in the conversation increases.

Typical reasons for ineffective listening, together with a brief explanation of each, are discussed throughout this chapter. As you read about each reason, think about your listening experiences and observe the conversations around you. See how many of these problems you can spot.

Distractions

Distractions are the most frequent cause of ineffective listening. A distraction can be almost anything that is detected by your senses while you are listening to someone else talk. It may be music or other voices that interfere with the voice to which you are listening. Likewise, it may be visual stimuli that you consciously or unconsciously notice, olfactory stimuli that you smell or tactile stimuli that you feel. Almost anything in the environment can become a distraction. Even things not in the environment such as your memory can operate as a distraction if something the speaker says triggers a recollection in your mind.

The distraction problem is especially acute if the listener must sit or stand quietly for long periods of time while listening to the speaker. The attention span of everyone is limited.

Examples of distractions that you may have encountered in job related listening probably include the noise made by nearby machines or equipment while you were talking, sudden changes in lighting or the atmosphere in the area in which you were speaking, or the appearance of a new smell. One or more of these distractions probably have interfered with conversations.

Emotions, Convictions and Biases

A second major cause of ineffective listening is a combination of factors called emotions, convictions, and biases. Often as you listen to a speaker, the words spoken and ideas expressed evoke strong feelings within you. Sometimes you feel anger, sometimes joy, and sometimes excitement. Each kind of emotion can cause you to tune out, unconsciously and unintentionally comments that are in opposition or contradiction to the primary emotion you are feeling.

Convictions are even more problematic than emotions for effective listening. Human beings have a tendency to listen to (and for) only those things that they want to hear. This means that people attend to information that supports their own views while they ignore information that contradicts their own opinions. Often the average listener actually edits conversations simply by cutting out the information that he or she disagrees with.

Biases also edit conversations, but usually in more insidious ways. Biases limit what the listener hears through preconceived notions about the speaker and the message *before* the message is delivered. For example, a listener may look at a speaker and decide that the speaker looks stupid or sloppy and unconsciously ignore whatever the speaker is saying. Likewise, a listener may decide unconsciously to disagree or devalue the message of the speaker without ever listening to it.

Examples of listening ineffectiveness due to emotion, conviction or bias that you may have encountered on the job include worker unwillingness or resistance to listen to a new supervisor because he or she is different from the old supervisor; because he or she is a woman, a minority or a disabled individual; or because he or she uses different mannerisms, speech patterns, or communication techniques. Emotions most frequently cause ineffective listening on the job when certain emotionally loaded words like "union", "boss", "scab", or "goldbrick", are used inappropriately. Emotions aroused by using inappropriate words and phrases result in the listener hearing the words, but missing the speaker's ideas.

Prejudging and Overstimulation

Sometimes when listeners are truly involved in a conversation, they become overstimulated by what is being said. This results in listeners leaping to premature conclusions about what the speaker is saying. For example, a listener may leap to premature conclusions and begin to form his or her own response before the speaker has finished speaking. Likewise, listeners sometimes leap to conclusions because they either disagree with part of what is being said and want to reinforce that idea with an example from their own personal experience. Similarly, listeners may disagree sharply with the speaker and want to challenge publicly what the speaker is saying. Sometimes the need to challenge an idea can be stimulated by a single idea or fact that listeners know to be incorrect. In their effort to concentrate on correcting that fact, the overall thrust of the speaker's argument is lost.

Emotional factors also can contribute to overstimulation and ineffective listening. On the job, this frequently happens to new or young employees who, when confronted by a supervisor they want to please, try so hard to listen to what is being said that they only hear a small portion of the comment while missing the gist of the conversation. In other instances, single phrases can trigger anger in ways that blot out everything else that is said. Further, no matter how hard the speaker tries to reorder what he or she is saying to help the listener understand, the listener's mental block may continue.

Prejudging also involves non-verbal factors of communication. Too often the type of clothes, the physical appearance of the speaker, the speaker's mannerisms or habits, or the speaker's voice tone and facial expression cause a listener to miss the spoken meaning of the words. While you must pay attention to these non-verbal clues in order to receive the complete message, if they contradict the verbal message, receive emphasis instead of the words, or simply do not support the words, they can be a problem. Further, if the non-verbal cues are similar to those used by the listener in certain situations, upon seeing them, the listener assumes the context will go in certain directions, regardless of whether it does or not.

Partial Listening

Partial listening is a factor that can take several forms including fragmented listening and pretend listening. Fragmented listening occurs when the listener listens only for certain points or facts rather than attempting to understand the entire idea being discussed. Pretend listening occurs when the listener either is uninterested in what is going on or is waiting for his/her turn to speak. In either case the listener does not concentrate on the message being delivered by the speaker and probably will miss what is being said.

One especially difficult type of partial listening is the tendency of everyone to avoid difficult subject matter. Often listeners may engage in the more elementary parts of the conversation, but "tune-out" as the content of the message becomes increasingly complex or difficult even though they may still pretend to be listening. The usual result is that listeners become completely lost because misunderstood sentences or missed words become cumulative. Soon they are helplessly lost in the conversation and do not/cannot respond *or* clarify the message.

Ineffective listening increases as persons get older, due largely to the individuals acquiring and practicing poor listening habits. The most frequently used bad habits have been depicted in Figure 3. Note that the list highlights the factors previously discussed.

Figure 3: Bad Listening Habits

1. Premature dismissal of subject matter as uninteresting or unrelated.
2. Criticizing speaker's apperance, mannerisms and delivery.
3. Becoming overstimulated by a remark and preparing your response before the speaker has finished talking.
4. Listening only for facts and/or minor points rather than the main idea.
5. Trying to outline everything you hear.
6. Pretending to pay attention to the speaker.
7. Noticing (or not working to ignore) distractions.
8. Avoiding difficult materials.
9. Permitting emotional words to affect the listener.
10. Wasting the time between the rate of speaking words and the rate of thinking.

Adapted from: Ralph A. Nichols and Leonard A. Stevens. *Are You Listening?* McGraw Hill Book Co.; New York; 1957.

Exercises

Answer the following questions about ineffective listening.

1. Imagine you are observing a conversation between a supervisor and an employee. The employee is complaining about a piece of equipment that continues to break. The supervisor's "beeper" goes off and the supervisor excuses himself. What happened and what would you recommend to the employee?

2. List all the poor listening habits you can recall.

3. Observe a typical conversation for 10 minutes. How many poor habits did you notice? Do this on-the-job and at home. In what settings does better listening occur?

Answers

1. distraction, start over with the compliant
2. refer to Figure 2.

Improving Listening Effectiveness

Because each individual is unique, it is impossible to establish a single set of rules for effective listening. However, there follows a set of strategies that you can use selectively to improve your listening skills. The basic idea is that while you listen, try to imagine yourself saying what the other person is saying. In that way, you can see where problems in logic or meaning exist.

Ask Clarifying Questions or Offer Clarifying Comments.

The most useful technique for effective listening is to ask clarifying questions or to make clarifying comments. A clarifying question is a question that you as a listener ask the speaker about what she or he said. In the question you state exactly what you think you understand the speaker to have said and ask if your understanding is correct. Frequently you will ask clarifying questions about both the main ideas of the conversation and more detailed facts or points. Usually, it is a good idea, when suggesting what you understand, to include examples that demonstrate what you believe you have learned. Do not be bashful or self-conscious in asking the questions because the conversation is simply wasted time if both parties do not benefit from the experience. Ask your questions in a positive manner that does not require the speaker to defend his or her position. Ask your question so that it permits the speaker to offer additional explanation or description. For example, imagine that another electronics apprentice is describing or showing you how to wire a particular circuit in a machine. The explanation is difficult because of the number of capacitors and resistors in the circuit. When the apprentice has finished his explanation, you are not sure you understand how to do the job. There are several ways you could question the speaker. You could say *"Would you expect that?"* or *"What does this capacitor do again?"* However, the most effective type of question would be a clarifying question that would indicate what you believe you understand from the explanation and ask if it is correct. Your comment might begin "If I understand this, first I believe...What do I have confused, and how?" If your understanding is correct, then ask a second question about some part of the explanation about which you are less certain. By indicating what you think you know, you identify for the speaker the areas where you need additional information.

A clarifying comment is a summary statement or a summary comment that you offer at the conclusion of the speaker's comment. It indicates what you believe to have been the main point of the speaker's comment. By using it, you ask if your understanding is correct. This means you must think about what the speaker is saying both in terms of the speaker's purpose and the message content. Then, before you answer the speaker's question or offer a related comment, you suggest what you believe you understood. The speaker must then either confirm or correct your understanding before you respond.

Adopt a Predisposition for Listening

Several techniques will help you be a more effective listener with relatively little effort. For example, as a listener, you improve the probability of understanding by: (1) assuming the speaker has something worthwhile to say; (2) avoiding and ignoring distractions including the urge to daydream; (3) looking at the speaker and standing or sitting quietly while maintaining eye contact; and (4) listening to the speaker's entire comment before forming an opinion or response. Each of these techniques improves your receptivity to information as a listener.

Think With and Ahead of the Speaker

Work with and ahead of the speaker to think about what is being said. More specifically, process the information so that you separate out, in your own mind, the speaker's purpose, facts, main ideas and opinions. For example, you need to identify for your own thinking the speaker's main idea. Once you have noted the main idea, then you can consider each of the supporting facts separately in order to decide if each is valid, reasonable, and supportive of the main idea. The main idea is usually the speaker's topic and conclusion. Supporting ideas are usually the evidence —— the points, facts and opinions —— a speaker uses to back-up or register the main idea. As you think about the evidence offered by the speaker, try to separate fact from opinion; then decide if the facts are valid, sufficient, and compelling. For opinions, decide if they are justified and logical. Further, note intended or unintended bias. Decide if the facts and opinions offered support the central idea and if they are relevant to your own information needs. Further, determine if the entire comment or argument is logical or reasonable.

Attend to Non-Verbal Messages

The words spoken are one message, the way they are spoken is a second message. You must "listen" to the non-verbal message because it reveals the true feelings of the speaker. Look for and listen for voice tone, gestures, eye contact and the other non-verbal cues mentioned earlier. Be particularly careful to note instances when verbal and non-verbal information reinforce each other as well as instances when they contradict each other. Both kinds of information are essential for understanding.

Figure 4 lists the better listening habits including those discussed above.

Figure 4. Good Listenting Habits

1. Look for areas of common interest or concern between yourself and the speaker.
2. Listen to content and non-verbal cues, but avoid non-verbal distractions.
3. Hear the entire comment before responding.
4. Listen for new ideas and supporting facts and opinions.
5. Listen for a while before taking notes or considering a response.
6. Work at being predisposed to listen.
7. Avoid or eliminate distractions.
8. Work at listening to difficult material.
9. Avoid being distracted by emotional words or phrases.
10. Use thought speed to think with and ahead of the speaker, considering, purpose, evidence, and logic.

Adapted from: R.G. Nichols and L.A. Stevens, *Are You Listening*? New York: McGraw-Hill Book Co., 1957.

Additional Information

For additional information about effective listening, you may want to read:

C.H. Weaver. *Human Listening*. Indianpolis: Bobbs-Merrill Educational Publishing, 1972.

E.A. Erway. *Listening*. New York: McGraw-Hill Book Co., 1979.

Self-Test Exercises

Answer the following questions about listening. Check your answers with those in the Appendix. If you answer 70% of the items correctly, continue work in the next chapter. If you score less than 70%, repeat your work in this chapter.

1. Approximately what percentage of all communication is verbal?

   (a)55% (c)75%
   (b)65% (d)85%

2. Explain what is meant by the "time difference" between the number of words per minute that can be spoken by the average speaker and the number of words that can be processed per minute by the average mind.

Answer:____

____

3. What is the most frequent cause of ineffective listening?

Answer:____

4. If a fellow apprentice says something that is partially wrong and you miss the part that is right in order to correct the part that is wrong, what has happened:

Answer:____

5. What is the most useful technique for effective listening?

Answer:____

6. How does assuming the speaker has something to say and looking at the speaker improve listening?

Answer:____

4. Asking Questions

Introduction and Objectives

Asking questions is the most useful and critical communication skill. A question expresses an idea and seeks a response from the person to whom it is asked. Questions are the principal communication tools available to you to gather and assemble information about the situations in which you find yourself. Among the purposes for which you as an apprentice can use questions are:

- seek new information about job requirements, work procedures and expectations;

- review and clarify your understanding of information, of directions or instructions, or major points and of summaries of activities;
- ask for and receive evaluations and feedback of work;
- focus attention on particular problems or concerns;
- request assistance or encouragement;
- offer assistance or encouragement; and
- build self-esteem, self-confidence and self-awareness.

The primary reason for asking questions is to gain additional information. There is a direct relationship between the type and form of question you ask and the type of informational response you receive. If you ask only specific, narrow and fact-related questions, then most likely you will receive specific, narrow and fact-related responses. If you ask a question that can be answered in yes and no terms, then most likely you will receive a yes-no response. If you ask a question that deals with information transfer and application, then most likely you will receive an information transfer or application response.

As you work through this chapter, you will learn about and practice asking questions. You will demonstrate your competence in this skill upon completion of the unit by being able to:

1. Critique questions so as to explain their strengths, limitations and major components; and
2. Construct and pose appropriate questions for various types of situations.

Principles, Examples and Applications

Good questions are questions that elicit the kind of response the questioner desires. Questions are judged by their clarity and their ability to elicit needed information. Clear questions leave no doubt about the purpose of the question. Further, good questions permit the respondent to focus on the concerns of the questioner, to elaborate on information or to explain the relationship of ideas and facts.

Questions are of different types and are grouped according to the type of information required to answer the question. For example, some questions are uncomplicated and require only simple recall of specific facts to provide the single right answer to the question. This is a question like "What tool is this?", such questions are called convergent questions. Other types of questions called divergent questions require that many types of information be presented to answer the question. An example of a divergent question is "How many different ways can you weld this type of joint?"

Asking good questions -- questions that are clear and that elicit the information you seek from the question -- requires practice and effort. The liklihood of your being successful in your questioning efforts is increased both with practice and by following several basic rules associated with asking questions. The basic rules are:

1. Identify Purpose(s) of Question

Before speaking, consider the purposes you want to achieve with your question. The purpose of your question is the "why" for asking the question. The purpose may be to acquire additional information; to clarify learner understandings of tasks, expectations, or prior learning; or to seek or offer help or assistance. Whatever the purpose, communicate it to your listener. Remember, your questions stimulate thought from the person to whom you asked the question in addition to meeting your individual information needs.

Sometimes your question may serve more than one purpose. When that is the case, phrase the question so that each purpose is clear and their order of importance is understood. It is your responsibility to phrase the question in understandable terms. The person to whom you ask the question cannot provide you with the answers you seek unless he or she understands what you want.

As you think about purpose, recall that the purpose and the intent of the question may not be the same thing. The purpose is the underlying reason for asking the question while the intent is the information or benefit you hope to achieve from asking the question. For example, say you have the task of taking down and cleaning up wooden forms used to pour concrete floors. You know how to use the hammer and nail-pull to take down the forms and take out the nails. You do not know, however, where to stack the lumber for future use or where to discard the unusable scraps. Therefore, you ask the crew chief where and how he or she wants the reusable lumber stacked and where to put the trash. Your purpose in asking the question was to seek new information in order to do your job as you understood it. Your intent was to learn exactly where to put the products of your next task.

Exercises

Consider each of the following several questions and identify the purpose and the intent of the question.

1. "How large in inches did you say that the pins we are making for that machine must be?"

   Purpose: Intent:

2. Where are the tools for lay-out and paste-up work?

   Purpose: Intent:

3. May I help you answer the customer's question?

   Purpose: Intent:

Answers

1. Purpose: Reconfirm understanding — Intent: Determine length of part
2. Purpose: New information — Intent: Locate needed tools
3. Purpose: Offer assistance — Intent: Determine if person to who question is asked needs/wants help

2. Phrase Question Carefully

Before you speak, consider exactly how you will phrase each question. When phrased properly, a good question will have the characteristics of: (1) conveying both your purpose and intent in asking the question; (2) using vocabulary shared by you and the person to whom you are asking the question; (3) being phrased so that it is grammatically acceptable.

Conveying purpose and intent. As indicated earlier, you must do this in order for the question to be understood and/or answered. A good question will leave no doubt about what is being asked, even if those to whom the question is put neither know the answer nor how to find it. Just say exactly what you mean. Further, when possible, avoid asking questions that can be answered simply by saying yes or no unless that is the information you want. For example, say for your related subjects information class you must calculate the force necesary to lift a load using various types of pulleys. You wonder if you must use the formula over again each time, or if there is some acceptable shortcut you could use within certain sets of questions. Before you ask the question, you phrase it two different ways in your head:

Option #1: Do I have to use the formula over again from the beginning for each problem?

Option #2: Would you please explain the rules about finding out how much force is needed to lift a load with different types of pulleys? I want to know if there is a shortcut I can use to save some time.

You realize that the first option provides an opportunity for a yes/no answer. In addition, it is somewhat unclear about the purpose and intent. Option 2 is better although it could still be improved. It clearly identifies both purpose and intent as well as avoiding yes/no types of answers.

Using vocabulary shared by you and the person to whom you are asking the questions. The most important rules about vocabulary are to avoid ambiguous statements and to use words and phrases appropriate to the task and that both you and the person to whom you are speaking understand. Too frequently the person asking the question assumes that the person to whom the question is being asked knows more than they do about whatever it is that the questioner is thinking. Remember, even when the two of you are working together, if you ask a question, you must set the limits on the answer and indicate the situation about which you are asking/thinking. Without the context, the person to whom you are speaking will not understand what you have asked or need. In addition, give as much information as possible about what you are asking in the vocabulary that you choose. Be sure to use words you both understand. Also use any job-specific terms that help to explain what you want to know. Be direct; do not beat-around-the-bush because it too often causes confusion.

The following example makes these points graphically. The situation is that of a beginning apprentice plumber who must solder copper pipe in a bathhouse and he does not remember the type of solder to use. The apprentice considers two ways of asking the question. The purpose is to get specific task information and the intent is to find out what kind of material to use.

Option #1: Am I right in assuming that acid flux solder is correct for use with copper tubing in a bathhouse?

Option #2: What kind of solder should I use on copper tubing that carries water?

Option two is clearly the less ambiguous question. Further, it uses more appropriate and direct language.

Phrasing question so that it is grammatically acceptable The language in your questions does not have to be perfect, but it does need to express your thought and do so in a way that does not make the person to whom you are speaking think that you are illiterate or stupid. The following grammatical guidelines will help:

1. Use the correct verb tense. Tense means the timing of verbs or when the action you are describing has, is, or will take place. The most important tenses are present, past and future tenses. Note that for regular tense verbs, the past tense simply adds an "ed" to the present tense while the future tense adds a "will" to the present tense.

2. Use accurate subject-verb agreement. Agreement simply means that the subject and verb fit with each other in terms of number (singular or plural). You must use plural verbs if the subject is plural.

3. Use pronouns correctly. Remember that the pronouns he, she and I usually are used in (as) subjects of sentences while pronouns him, her and me usually are used as objects and in predicates of sentences.

4. Use complete sentences. Usually it is best to include only one idea per sentence. Avoid cramming too much information into a single sentence and never leave thoughts or words dangling.

3. Ask Questions in a Manner that Encourages the Response You Want.

After thinking about the question and phrasing it in your mind, you must ask it in a way that will encourage an answer. The considerations you must make in asking questions are: (1) timing; (2) voice; and (3) tact/assertiveness. In terms of timing, ask the question at an appropriate moment. The appropriate moment may be during the period when the information is being used, during a set-aside period for asking questions, before or after work (or class) or during a break, or any of a variety of other times. Avoid asking questions at awkward, embarrassing or dangerous times and always provide enough information in your question so the person to whom you are speaking can identify the situation about which you are speaking.

Your voice is important. In asking questions, emphasize those points that are of greatest importance. Ask the question directly and distinctly and make sure that you show some enthusiasm. *What you say and how you say it* are of almost equal importance as the question itself.

Use tact and assertiveness in asking your questions. If you demonstrate that the answer is important to you, you increase the probability of a careful, useful and prompt answer. It is usually a good idea to avoid asking (or implying) evaluative information in your questions. Instead you get the best information in response to probing and exploratory questions that are non-judgmental.

Once you have asked a question and have received a response, you must do two other things. First, acknowledge that the question has been answered through a comment, a gesture or by paraphrasing the answer. The paraphrasing is especially useful because it confirms to the other person your understanding of the answer.

Second, do something with the answer you received. Use it, reject it, store it or in some other way indicate to the respondent that you value their time/effort enough to attend to the answer. Using the answer -- if it is correct and useful -- is the best way to keep your credibility with the person with whom you spoke.

Self-Text Exercises

Answer each of the following questions and check your answers against those provided in the Appendix of this book. If you answer 70% of the items correctly take the Posttest at the end of the booklet. If you score less than 70%, repeat your work in this chapter.

1. How are the type of question asked and the type of answer received related?

   Answer: ____

2. Remember that a question's purpose is the underlying reason for asking it while the intent is the exact information you hope to receive in response. Read the following questions and identify the purpose and intent of each.

   a) Foreman to apprentice.
   "How do you think that line is supposed to be run?"
   Purpose:____________________ Intent:____________________
   b) Apprentice to apprentice
   "Roger, will you explain to me how the hydraulics of this lift work?
   Purpose:____________________ Intent:____________________

3. Why are tact and assertiveness important in asking questions?

   Answers: ____

4. Once you have asked a question and received an answer, what must you do?

   Answer: ____

5. Appendix

Answers To,Self-Test Exercises

Chapter 2: Communication Requirements and Components

1. Listening
2. (a) deciding what to say; (b) getting attention; (c) speaking
3. Actions
4. b.
5. Jargon are words that have meaning only for small groups of people. Someone outside the group will not share the meaning of the word and so will not understand what was said.

6. Description of behavior deals with observable action. It does not deal with *"why"* so it requires fewer guesses and reduces the need of the person to whom feedback is given to be defensive. Behavior is obvious and can be described and discussed by everyone who observed it.

7. a) organize information and work through it systematically
   b) consider audience
   c) use examples
   d) avoid distractions
   e) ask questions

Chapter 3: Listening

1. d

2. People can think more quickly than they can speak. This means that as you listen you have extra "time" above and beyond required time for listening that can be used either constructively or that can be a distraction.

3. Distractions

4. As a listener, you become overstimulated or prejudged the information and missed some critical aspects of what was said.

5. Asking clarifying questions or offering clarifying comments.

6. It improves a predisposition for listening by encouraging the listener to avoid distractions and concentrate and by making the speaker aware that someone is listening to him/her.

Chapter 4: Asking Questions

1. The type of question asked usually determines the type of answer/information received. If you ask a yes-no question, you usually will get a yes-no answer. If you ask an unclear question, you will receive an unclear answer.

2. a. Intent: Check apprentice knowledge   Purpose: Directions for procedure

2. b. Intent: New information   Purpose: Explanation of process

3. They demonstrate that the question and answer are important to you as the questioner.

4. Acknowledge receipt of the answer and use the information.

Posttest

Directions: Answer the following questions and compare your answers with those provided. For those questions where your answer and the suggested answer correspond, consider the skill learned. For those items where your answer and the suggested answer differ, review the materials in the booklet. Score your test according to the sections at the end of the answer sheet.

1. What are the three parts of the communication process?

   Answers:

   a) ____

   b) ____

   c) ____

2. What happens to your message if you say one thing but do something else?

   Answer: ____

3. Which of the following types of communication devices is *least* useful for clearly conveying and understanding a spoken message? (Circle only the letter of the best answer)
   a) examples

   b) eye contact

   c) feedback

   d) repetition

4. Examine each of the following non-verbal situations and indicate the effect of the behavior on the speaker or the listener (whichever is designated).
   a) eye contact between speaker and listener on the speaker: ______________________
   on the listener: ____

   b) listener squarely facing the speaker, sitting comfortably and slightly inclined toward the speaker.

   on the speaker: ____

   c) speaker's fluctuating voice tone on the listener: ______________________

5. Consider the following communication situation and suggest at least four ways about how the feedback was useful as well as how it could be improved.
   Anne Clark, a journeyman printer, was speaking with three apprentices about the Offset and Heidelberg presses. She provided comments to each apprentice individually, detailing what she had observed them doing in their work. She indicated areas of strengths and limitations using individual samples. She suggested better procedures when problems were noted. She also asked why apprentices had performed certain ways.

6. Joe Fox, a related subjects instructor, was lecturing on Pascal's Principle, explaining how hydraulic systems work. He had talked for ten consecutive minutes using a carefully organized lecture about the background, math and science theory involved with the principle. He noticed the apprentices daydreaming. What two things might you suggest to him to better stimulate learner interest?

7. How do emotions, convictions and biases affect effective listening?

8. What three techniques can you use to encourage yourself to listen to and process difficult information.

9. Identify the purpose and intent of the following questions.

   a) "Am I correct in using this bit to drill out the bolt?"

   Purpose: ______________________ Intent: ______________________

   b) "How should I tie into this electrical box?"

   Purpose: ______________________ Intent: ______________________

10. Read the following questions and point out the potential problems with each.
    a) Apprentice to related instructor requesting assistance with math: "How do I perform metric conversions?"

    b) Apprentice to apprentice about local campaign: "What's in the new union for us?"

Answers To Posttest

1. a. Initiating b. Attending c. Responding

2. Message becomes confused and audience is more likely to believe action as opposed to words.

3. d.

4. a. Speaker: eye contact from listener indicates interest and support.
   Listener: eye contact from speaker indicates sincerity.
   b. Speaker finds support and encouragement from listener's behavior.
   c. Listener notes areas/points for emphasis from the speaker.

5. Useful because (a) of individual attention/comments; (b) dealing with observation and observed behavior; (c) make points using examples; (d) pointed to strength and limitations; (e) dealing with current events; (f) suggested improved practices could be improved (g) by talking about the "what" and avoiding the "why". (Correct if you got at least 4 of the 7)

6. (a) Use examples; (b) Vary voice tone to add emphasis; (c) Speak in the language of the audience; (d) Ask questions; and (e) Use visual or model materials. (Correct if you got 2 of the 5)

7. Emotions, convictions and biases affect listening by distracting the listener through overstimulation, by encouraging the listener to hear only a small part of the comment or by encouraging prejudging before the comment is completed.

8. Techniques include: (a) Making clarifying comment; (b) Thinking with and ahead of the speaker; (c) Attending to non-verbal messages; (d) Adopting a predisposition for listening; (e) Avoiding distractions; and (f) Listening to idea before judging.

9. a.Purpose: Confirm an understanding Intent: A yes or no response
   b. Purpose: New information Intent: Directions for procedure

10. a. It is ambiguous; What does the apprentice want or need? It has no distinguishable purpose or intent. Also, it is in rather formal language.
    b. It is ambiguous with little information to respond to.

Competency:

1. Demonstrate safe practices necessary in the trade.

Instructional Objectives:

1. Describe safety awareness.
2. Identify causes of accidents.
3. Define unsafe acts.
4. Describe safety planning.

Learning Activities:

1. Read the General Safety Information Sheet.
2. Complete the General Safety Self-Test.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. A copy of the information sheet, self-test questions and answers, and test and answers is included with this unit.

Resources:

1. Booklets:
   - A. NAPHCC Safety Manual available from the National Association of Plumbing, Heating, and Cooling Contractors,
     180 S. Washington Street, Falls Church, VA 22046,
     (800) 533-7694.
   - B. What a Journeyman Should Know About Electricity also available from NAPHCC.

2. Audio-Visual Materials:
   - A. "Personal Safety" and "Industrial Safety" are available from NUS Training Corporation. Both videotapes focus on plant hazards, safety equipment, and accident prevention.
   - B. "Electrical Safety in Low Voltage Situations" is available from Marshall Maintenance Productions. The videotape presents an introductory program designed to familiarize workers with the basic guidelines for working safely with electricity.
   - C. "Electrical Safety" is available from Tel-A-Train. The videotape covers the various hazards involved with even minor electrical work.

General Safety Information Sheet

THE IMPORTANCE OF SAFETY

Employees owe it to themselves, their families, their co-workers, and their employers to work in the safest manner. Unless safety principles and practices are faithfully observed every day, the time and effort an apprentice puts forth in learning a trade could become a tragic waste.

By their very nature, occupations within the industrial trades are hazardous, and an employer or an employee who lacks concern for on-the-job safety contributes toward an increased possibility of accident or death on the job.

This topic is designed to help apprentices become aware of some of the hazards of the trade, to help them become safety minded, and to enable them to use their reasoning powers to recognize dangerous situations.

For the past several years, the number of employees killed has averaged 14,200 a year. From 1960 through 1970 there were over 150,000 fatalities. In 1972, more than 50 million employee-days were lost because of disabling injuries, and the known cost of accidents--not counting property damage--was over $11.5 billion. Unknown costs, resulting directly from accidents but not recorded, or not possible to record, are several times higher. These figures do not include most of the deaths and disabling illnesses from occupational disease. Most of these were not recorded before enactment of the Williams-Steiger (OSHA) Act of 1970.

Recently, employers, unions, employees, and various government agencies have seen the need for developing effective programs to improve occupational safety and health. The importance of keeping employees safe and healthy has achieved such wide-spread recognition that a broad and detailed national program finally has emerged. Everyone is beginning to realize there is an obligation to protect individuals from on-the-job accidents and illnesses.

While more than 50 million employee days were lost in 1972, it's obvious that great losses in employee productivity were recorded. For example, it would take 188,000 men working for one year, five days a week, eight hours a day, with no vacations or time off, to make up for this lost time. These figures point out that too many employees are disabled from industrial accidents. However, many disabling injuries can be prevented.

CAUSES OF ACCIDENTS

An accident is an unplanned and unforeseen occurrence that interferes with or interrupts the orderly progress of an activity. Although by this definition accidents do not necessarily involve injury or death, in fact they all too often do. Accidents that do occur should be analyzed to determine why and how they occurred and to determine what steps should be taken to ensure that similar accidents do not occur again. Accidents are caused for the most part by unsafe conditions, unsafe acts, or some combination of these two hazards.

Unsafe conditions on the job site may be present in the form of equipment that is poorly designed or constructed, improperly installed, or badly maintained. Unguarded equipment, defective or wrong hand tools, poor housekeeping, and inadequate lighting are common factors that make for unsafe working conditions.

UNSAFE ACTS

Unsafe acts are violations of safe working practices. Wearing loose-fitting clothing on the job, operating machinery without the required guards or improperly throwing instead of carrying materials, lifting or carrying with the back bent, and engaging in horseplay on the job are all examples of unsafe acts.

Unsafe conditions and unsafe acts are both threats to the worker's safety, but the majority of industrial accidents are caused by a combination of these hazards. A wheelbarrow with cracked or loose handles (unsafe condition) may not play a part in an accident until a worker attempts to move a heavy, unbalanced load in it (unsafe act). A power saw with an unguarded blade is not likely in itself to cause an accident, but a severe injury can result if a worker disregards the unsafe condition of the machine and as a result gets his hand in the way of the blade.

PREJOB SAFETY PLANNING

Although a great deal of time and money have been spent by safety-oriented organizations to improve accident-prevention efforts on the job site, prejob planning continues to be of the utmost importance in providing for safety. This planning is a cooperative effort and demands the participation of all concerned. During the prejob planning, an attempt is made to establish rules for safety on the particular project, to anticipate problems that could arise, and to determine appropriate methods for protecting the persons involved with the job and the job site.

THE WILLIAMS-STEIGER OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970

In the decade of the 60's, a sharp increase of job related accidents occurred (29%). A wider use of new chemicals and hazardous materials created a greater source of unsafe conditions. Labor's concern for a safe workplace pushed for passage of legislation and in 1970 the Williams-Steiger bill was passed. You know it as OHSA, the Occupational Safety and Health Bill of 1970.

In passing the Williams-Steiger Occupational Safety and Health Act of 1970 (OSHA), the federal government declared safety on the job to be everyone's responsibility. The purpose of OSHA, which became effective in 1971, is to preserve human resources and to ensure so far as possible that every worker in the nation will have safe and healthful working conditions. This law applies to all states and U.S. territories, but it provides that the states may develop their own plans for meeting the requirements of the law.

RESPONSIBILITY OF EMPLOYERS

The Williams-Steiger Act requires that every employer furnish his/her employees a place of employment that is free from recognized hazards that might cause serious injury or death. The act further requires that employers comply with the specific safety and health standards issued by the U.S. Department of Labor.

RESPONSIBILITY OF EMPLOYEES

In accordance with the provisions of the Williams-Steiger Act, all employees must comply with safety and health standards, rules, regulations, and orders issued under the act and applicable to their personal conduct.

ADMINISTRATION OF THE WILLIAMS-STEIGER ACT

The administration and enforcement of OSHA are vested primarily in the Secretary of Labor and the New Occupational Safety and Health Review Commission. The basic purpose of the Act is "to assure, as far as possible, every working man and woman in the nation safe and healthful working conditions and to preserve our human resources." The "safe and healthful working conditions" will be assured by authorizing enforcement of the standards developed under the Act. Assisting and encouraging the states in their efforts to assure safe and healthful working conditions and providing for research, information, education, and training in the field of occupational safety and health are also intents of the Act. OSHA covers about 60,000,000 people in 5,000,000 workplaces; excludes Federal employees, State and political subdivisions thereof and certain waterfront workers.

APPRENTICESHIP AND SAFETY

A major goal of all apprenticeship programs is to provide the apprentice with the knowledge and skills needed to work safely in his or her trade. Much time, effort, and money will be devoted to making an apprentice a skilled craftworker, all of which will be wasted if an industrial accident cuts short the apprentice's career and perhaps, life.

Apprentices are expected to learn how to work safely; to study the laws governing safety; to understand the principles upon which safe work practices are based; and to conduct themselves at all times with due consideration for their own safety and that of their co-workers.

The apprentice should keep in mind that accidents do not just happen. Accidents are caused by people, and they happen most often to people who fail to work in a safe manner.

VOCABULARY

Terms and Definitions

A. OSHAct--An abbreviation for the Occupational Safety and Health Act of 1970. The Act provides for minimum safety and health standards for working conditions. It is a Federal Act of Congress.

B. OSHA--An abbreviation for the Occupational Safety and Health Administration. OSHA is part of the United States Department of Labor and its main duties are to:

    1. Encourage employers and employees to reduce hazards in their workplaces.
    2. Establish responsibilities and rights of employers and employees.
    3. Encourage new safety and health programs.
    4. Establish record keeping procedures to keep track of injuries and illnesses that happen on/or because of the job.
    5. Develop standards and enforce them.
    6. Encourage the states to establish safety and health programs.

D. Standards--These are the rules that are set up by OSHA to provide minimum assurance of on-the-job safety. There are two types of standards:

    1. Horizontal standards - those applying to all industries.
    2. Vertical standards - those applying to one special industry.

D. Variance--This is an exemption for an employer from a particular standard. There are several types of variances:

    1. Temporary - when a standard cannot be complied with so other arrangements are made for the time being.
    2. Permanent - when a means different from the standard provides adequate safety and health conditions.
    3. Experimental - when testing new methods of safety.
    4. Other - when there is a national emergency situation.

E. Accident--An unplanned, uncontrolled event which results in personal injury or the chance of personal injury. Accidents cost the U.S. at least $47 billion a year. Of this, $16 billion is due to accidents at work. Work accidents kill more than 12,000 people and cause over 2,000,000 disabling injuries per year in the U.S.

F. Hazard--Something that is potentially dangerous and if not corrected could cause an accident.

G. Safety Director--The person responsible for putting a good safety program to work and keeping it running effectively on a company-wide basis. In large companies there may be a full-time safety director, while in small companies the personnel director may act as the safety director along with his or her other duties.

Reference:

1. Related Training Modules for Stationary Engineer. Eugene, Oregon: Lane Community College, 1985.

General Safety Self-Test

Determine the correct word(s) for each statement and fill in the blanks.

1. Accidents are caused for the most part by unsafe ____________________, unsafe ____________________, or a combination of these hazards.

2. In passing the Williams-Steiger Occupational Safety and Health Act of 1970, the federal government declared that on-the-job safety is the responsibility of ____________________.

3. The responsibility for administering the Williams-Steiger Act rests with the Secretary of ____________________.

4. Anyone known to be under the influence of ____________________ ____________________ should not be permitted on the job while in that condition.

5. Employees should be alert to see that all guards and other protective devices are in their proper places and adjusted, and they should report any deficiencies to the ____________________ or ____________________.

6. Repairs or adjustments to machinery should not be made while the equipment is in ____________________.

7. A worker whose regular duties do not include operating machinery or equipment should not attempt to do so without special ____________________.

8. An accident is an ____________________ and ____________________ occurrence.

General Safety Self-Test Answers

1. conditions, acts
2. everyone
3. labor
4. intoxicants, drugs
5. foreman, safety supervisor
6. motion
7. permission
8. unplanned, unforeseen

General Safety Test

Decide which of the four answers is correct, or most nearly correct; write the corresponding letter in the blanks at the left of each question.

1. _____ Provisions of the Williams-Steiger Occupational Safety and Health Act of 1970 require that employers comply with safety and health standards issued by the

   a. U.S. Senate
   b. Division of Industrial Safety
   c. U.S. Department of Labor
   d. none of the above

2. _____ Workmen's compensation laws have been passed so that workers injured on the job may receive benefit payments

   a. only if the injury was the employer's fault
   b. only if the injury was the employee's fault
   c. if insured through an authorized insurance carrier
   d. in the case of any industrial injury

3. _____ In the lifting of loads, the weight should be carried mostly by the muscles in the

   a. legs
   b. back
   c. arms
   d. abdomen

4. _____ A good program of accident control must include

   a. offering rehabilitation training to injured workers
   b. firing employees who have accidents
   c. correcting unsafe working conditions and practices
   d. putting up safety posters

5. _____ Which of the following is an unsafe act?

   a. sawdust on a stairwell
   b. a ladder with a broken rung
   c. wearing loose-fitting clothing on the job
   d. poor housekeeping

6. _____ OSHA is a result of

   a. expanding federal government
   b. a decision by construction foremen
   c. the safety and health review committee
   d. labor's concern for a safe workplace

7. _____ During a typical year, in the past few years, the number of employees killed was near

a. 200
b. 750
c. 12,000
d. 100,000

8. _____ Which of the following is not a variance?

a. temporary
b. horizontal
c. experimental
d. permanent

General Safety Test Answers

1. d
2. d
3. a
4. c
5. c
6. d
7. c
8. b

Competency:

1. Recognize safe use of tools and equipment used in the trade.
2. Identify proper procedures and potential problems of ladder and scaffold use.
3. Recognize equipment and clothing used to protect against hazards in the work environment.

Instructional Objectives:

1. Identify unsafe work situations involving tools and equipment.
2. List safe work practices for using tools and equipment.
3. Identify how to develop safety skills.
4. List the consequences of unsafe work habits.
5. Select typical hazards associated with ladder and scaffold use.
6. Identify appropriate safety procedures for using ladders and scaffolds.
7. List situations where protective equipment or clothing is needed to work safely.
8. Explain the hazards of not using protective devices or clothing properly.
9. Identify some of the types of protective clothing and equipment available for use.

Learning Activities:

1. Read Chapters 3, 4, and 5 in Basic Safety II - Apprenticeship Related Instruction.
2. Complete the Self-Test Exercises at the end of each chapter.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. Rice, E. and Spetz, S., Basic Safety II - Apprenticeship Related Instruction. Raleigh, North Carolina: Conserva, 1982. A copy of chapters 3, 4, 5 is included with this unit.
2. A copy of the self-test exercises and answers and a copy of the test and answers is included with this unit.

3. Using Tools And Equipment Safely

Introduction And Objectives

Accidents resulting from the unsafe use of tools or equipment can be particularly serious. Shocks from faulty tools can cause burns or even death. Unsafe operation of power equipment can lead to minor loss time accidents as well as such serious disabilities as loss of an arm or your life. A worker who is not adequately trained in the use of tools is particularly susceptible to these hazards. But even the well-trained worker has accidents resulting from carelessness, inattention or boredom. This chapter will help you to avoid accidents in the workplace by using tools and equipment safely. After completing this chapter you will be able to:

1. Recognize unsafe work situations involving tools and equipment.
2. List safe work practices for using tools and equipment.
3. Recognize the consequences of unsafe work habits.
4. Identify how to develop safety skills.

Principles, Examples And Applications

Tools and equipment are designed to modify materials through the use of force. This may involve a very simple operation such as driving a nail with a hammer. On the other hand, the operation may be more complex such as the turning of a metal rod under numeric control. No matter how complex the operation, the fact that use of tools and equipment involves some type of force puts you in danger. For example, through carelessness, the force from a hammer could be transmitted to your thumb rather than the nail head. Power tools and equipment impose more serious hazards. Moving parts, such as in running gear wheels, revolving shafts, driving motors and belts, blades and punches, all are potential dangers.

Power tools have the added hazard of electrical shock. On high-voltage equipment or in a wet environment, shocks can be deadly. Low-voltage shocks can also be serious by indirectly causing an accident, such as a fall from a scaffold. Safeguards against shock are generally built into tools and equipment. But you as a worker must be responsible for assuring electrical safety. Electrical safeguards include:

1. Use a ground wire: This assures that electrical leaks go to ground through a wire rather than the tool user. This requires a three-prong outlet and extension.
2. Use low voltage: if a shock occurs, it is of lower intensity.
3. Use double insulated construction: This completely insulates the user from electrical current. There is no need for a ground wire.

Most modern equipment has built-in guards to protect the worker from mechanical hazards. These range from a trip switch to automatically shut-off equipment, to screens that prevent fingers or other body parts from entering hazardous areas, to automatic guards which push a worker out of the way of moving parts. The design of the job also can counteract hazards. For example, devices other than hands can be used to feed material into machines for processing. Even so, it is still up to you to follow such operating procedures and to ensure that guards remain in place and are operating properly. By becoming aware of the risks in your work environment you take the first step in being a safe worker.

Safe Work Practices

Each different tool or piece of equipment has proper and safe procedures for operation. For example, a wrench should be pulled toward you rather than pushed away from you to use it safely. Likewise, an adapter should not be used to connect a grounded plug to a two-pronged outlet. The following guidelines are some general safety procedures and sample consequences of not following the guidelines. Before using a tool or equipment you should find out about its safe operation from your supervisor, safety notices, manufacturers' operating and maintenance instructions and manuals.

Table 1: Safe Work Practices For Using Hand Tools

Safety Guidelines	What Could Happen If You Do Not Follow Guidelines
1. Keep tools in good condition — clean, oiled, free from rust, cracks, chips.	Tools in bad condition can break, slip or perform poorly. This can cause you to hurt yourself — for example wrenching your back when a tool slips. Or the tool itself can cause injury as in the case of a sledge hammer head that flies off a broken handle.
2. Store tools in a safe place.	Tools not put away can be used by someone not trained in their use. They also can get in the way of an unaware worker. For example, a wrench left in the wrong place can cause someone to trip or it can fall on someone's head.
3. Select the proper tool for the job.	Using the wrong tool can cause the tool to break, slip or perform poorly. You also can strain a muscle or sustain another body injury by using the wrong tool.
4. Use tools correctly.	Using a tool incorrectly can cause an injury to you or a co-worker. For example, many injuries occur from people cutting toward themselves rather than away when using a blade.
5. Use a tool box, cart, belt or pouch to transport tools, instead of in pockets or hands.	You may need your hands to help you maintain your balance on a ladder or scaffold. Tools in pockets can cause a puncture or other injury.
6. Hand tools to co-workers rather than throwing them.	The tool may hit the co-worker causing an injury or he/she may lose their balance reaching to catch a tossed tool.

Table 2: Safe Work Practices For Using Power Tools And Equipment

Safety Guidelines	What Could Happen If You Do Not Follow Guidelines
1. Inspect tools and equipment periodically. Check: — That the motor is operating smoothly — That guards are in place and operating freely — That tools and equipment are clean, lubricated and sharpened — The condition of cords, plugs, and insulation, for cracks, breaks, loose connections — That controls operate and release correctly — That parts are not loose or missing — That the workhead moves freely by hand when unplugged	For tools to operate properly they must be in proper condition. Any number of accidents can occur from not inspecting and maintaining tools, including electrical shock, fire, and bodily injuries from tool malfunctions.
2. Maintain tools as needed and directed in manufacturer's instructions, including cleaning, lubricating, sharpening, and any minor repairs for which you are trained. Have other problems fixed by a trained service person.	
3. Store tools where they are protected and out of the way.	Misplaced tools can be damaged or cause injury by falling on someone or getting in the way.
4. Do not hang cords over nails or other sharp edges or leave them loose on the floor.	Insulation can become damaged causing a potential for shock. Someone can trip on a cord in the floor.
5. Use the correct tool for the job: — Use proper size tool — Use proper duty rating of tool — Use proper accessories (bits, blade, disks, etc.)	An improper tool or accessory will not do the job as efficiently. Also, jamming or over working can cause the tool to break causing shock or other injury.
6. Follow standard operating procedures in using tool.	A shock or other injury can result from using a tool improperly.

Table 2: Safe Work Practices For Using Power Tools And Equipment (Continued)

Safety Guidelines	What Could Happen If You Do Not Follow Guidelines
7. Turn off and unplug tool before cleaning or making adjustments.	A surprise start-up of a tool can directly cause an injury or indirectly cause you to hurt yourself by startling you.
8. Wear required protective materials (gloves, shields, goggles, shoes, etc.)	Flying particles or objects can injure unprotected parts of your body.
9. Use low-voltage tools in wet areas.	Wet objects conduct electrical current much better. Thus, you are much more prone to a serious shock when wet. By using low-voltage tools you limit the intensity of a shock.
10. Use correct size fuses.	If a fuse does not cut off when it should, you can be shocked.
11. Use correct voltage.	A tool/machine operating at a speed it is not designed for operates inefficiently and can even burst at high speed.
12. Secure the piece you are working on.	While holding the piece in one hand and operating a tool in the other, it is easy to lose your balance and more difficult to react to unexpected occurrences.
13. Keep the work area clean.	It is difficult to walk in, see in and work in a messy work space.
14. Do not wear loose clothing, jewelry, long hair when operating tools and equipment.	Loose objects can easily become entangled in a tool head or motor, drawing you into a dangerous or deadly area.
15. Walk only in designated aisles or passageways. Keep these areas open.	Walking in non-passage areas exposes yourself to hazards. You may also interfere with someone else's work by being in the wrong place and cause them to have an accident.

Exercise

Make a check list of the guidelines listed above. Check your work practices for a one-week period. How many of the practices did you follow in using tools and equipment? Did you perform any of the activities in an unsafe manner? What were the consequences? What could have happened?

Developing Safety Skills

Whenever you work with tools or equipment you are exposed to a number of hazards. By developing safety skills you can reduce the impact of these hazards. Follow three steps to develop safety skills in working with tools and equipment:

1. *Develop an awareness of the risks and hazards.* Evaluate your work environment to determine what types of hazards exist. Find out about the tools and equipment. What are the moving parts? How are the machines guarded? How do these guards work? Where and how have accidents occurred in the past? Look for any work practices or situations which appear to be dangerous. Make notes of the hazards and think about them so that they are always in the back of your mind when working. This way you will be ready for the unexpected.
2. *Learn to operate, adjust, and maintain tools and equipment safely.* Find out specific operating procedures through on-the-job training, from your supervisor and co-workers. Find out who has the best safety record and watch how they operate tools and equipment. Make a list of the applications and limitations of your tools and learn them. Finally, practice using tools and equipment under supervision until you have mastered safe operating procedures.
3. *Be alert.* Many accidents are caused by carelessness. Pay attention to what you are doing, while keeping aware of the job hazards. Be alert to any changes in sound, vibration, operation, or feel of your tools and equipment. Most of all, respect them.

Additional Information

For additional information you may wish to read:

Accident Prevention Manual for Industrial Operations, Seventh Edition. Chicago, IL: National Safety Council, 1974.

Manual of Accident Prevention in Construction. Washington, DC: The Associated General Contractors of America, Inc., 1949.

Safety and Health Series. Waco, TX: Center for Occupational Research and Development, 1982.

Self-Test Exercises

Read and answer the following questions. When finished, check your answers with those provided in the Appendix. If you score 7 or 8 correct answers, move on to the next chapter. If you answer less than 7 items correctly, repeat your work in this chapter.

1. What are two major types of hazards in using power tools and equipment?
   a. ____________________
   b. ____________________

2. List three conditions that increase the chance of electrical shock when working with power tools.
   a. ____________________
   b. ____________________
   c. ____________________

List three things you should check when inspecting a power tool:

3. ____________________
4. ____________________
5. ____________________

What are the three steps to developing safe working skills?

6. ____________________
7. ____________________
8. ____________________

4. Using Ladders And Scaffolding Safety

Introduction And Objectives

Use of ladders and scaffolds is one of the major hazards on the construction job site. Hazardous conditions include improperly securing the ladder, scaffold or bracing; broken or substandard materials; and errors in ascending or decending. Most ladder and scaffold accidents are preventable if you exercise care and good judgment before using the equipment. In this chapter you will learn about ladder hazards and safety as well as a set of general rules that apply to the use of scaffolding. When you have completed your work in this unit you will be able to:

1. Recall and identify typical hazards associated with ladder and scaffold use; and
2. Suggest appropriate safety procedures for using ladders and scaffolds.

Principles, Examples And Applications

Ladder Hazards And Safety

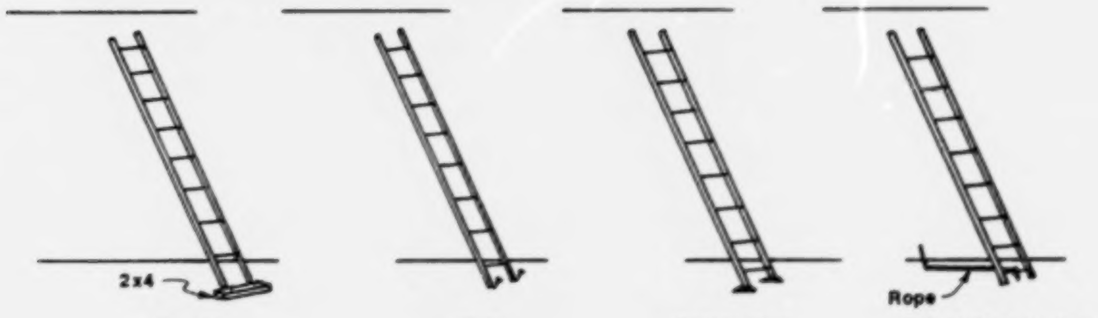
Ladders are tools that are abused too frequently on the job, with very serious results. Carelessness and ignorance result in thousands of work-related ladder accidents each year, hundreds of which have permanent outcomes. The vast majority of such accidents and injuries are avoidable if you are aware of ladder hazards and if you know and practice ladder safety. Remember, ladders of some type are used in most apprenticeable occupations and only *you* can be responsible for your own safety.

Before using a ladder, always check for loose or missing rungs; broken sides, braces, or spreaders; and poor stability. If a ladder has these problems, *do not use it.* Find another ladder. Be particularly wary of painted wooden ladders because the paint can conceal dangerous faults in the wood.

Be sure that all rungs of the ladder are parallel and level to the ground. No rung should be more than 12 inches from any other rung and the ladder should be about a foot wide. Do not stand on the top rung of a ladder; instead, use a longer ladder. Also avoid climbing on the ladder braces and be sure that, if you are using a step ladder the legs are fully extended and locked. Do not use a step ladder leaned against a wall.

The rules for using a ladder may vary slightly with the type of ladder. Even so, the general rules apply. Follow these rules for your health:

1. Use only sound ladders. Avoid defective equipment.
2. Use a ladder with safety feet suitable to the surface on which it stands. The bottom should rest on a solid, level surface. If no safety feet or non-slip provisions are available, either nail the bottom of the ladder to the floor or place the bottom of the ladder against a safety cleat. Figure 1 illustrates these techniques.



Cleat Nails Safety Feet Tie or Hold Ladder

Figure 1: Ladder Bottoms

3. The top of the ladder should extend about three feet above the top of the surface to which you are climbing or above the level on which you are working.
4. Avoid placing the ladder in front of a door or entrance into a structure. If the ladder must be placed in that area, lock or close off the entrance. Never lean the ladder against a window

pane or sash. Always avoid leaning the ladder against stacked materials. Never use a metal ladder around electrical wires.

5. If you use a step ladder, be sure that the ladder is fully extended and locked before you climb.
6. Place barricades or warnings around the base of the ladder to warn passers-by of your presence.
7. Place the ladder against the wall so that the distance of the base of the ladder from the wall is equal to about 25 percent or one-fourth of the working length of the ladder. This means that the base should be set away from the vertical surface one foot for every four feet of working length of the ladder. This will result in an angle between the ground and the ladder of about 75 degrees. Figure 2 illustrates this point.

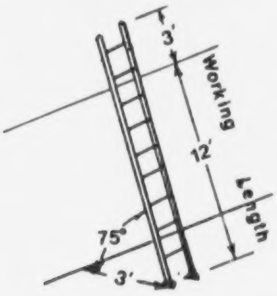


Figure 2: Ladder Placement

If the bottom of the ladder is too close or too far away from the wall, the ladder will either slip or topple backwards. If you feel comfortable and do not have to lean as you begin to climb, the angle is probably correct.

8. As you climb, have another worker hold the ladder. Climb by facing the ladder and holding on with both hands. Carry all tools or materials in comfortable, out-of-the-way tool belts or have them hoisted up to you.
9. Work only a comfortable reach on all sides of the ladder. Do not hesitate to move to a new spot rather than reaching long distances.
10. Do not strap or splice ladders together to make a longer ladder. Instead, use an extension ladder of 60′ or less.
11. The overlap of the sections of an extension ladder is about 10 percent of the extended length of the ladder. Therefore, for a 36′ ladder, the overlap would be at least 3′; for a 40′ ladder it is 4′ and for a 48′ ladder it is 5′. Remember, it is safer to have too much overlap rather than too little. Always make certain the extension section is securely locked.
12. If necessary, brace or secure long ladders in the middle to eliminate the spring and make them more rigid.

In addition to these rules, remember that, especially with extended ladders it usually is a good idea to have someone else help you set up the ladder. First secure the base, then walk the ladder into the air. Also, *always* before climbing, check to be sure the ladder is secure *and* wipe any grease, mud and other materials from your shoes and hands. Further, when climbing on fixed ladders, use a cage or safety belt.

Scaffold Safety

Scaffolds are elevated platforms that support workers and materials. They are temporary; their height is increased as work proceeds vertically and they are removed when work is completed.

In general, scaffolds must be constructed from sound materials placed on a solid base. Further, rails, toe boards and guards should be used to prevent possible injury to those below from dropping objects off the scaffold. Do not build scaffolds on loose materials such as loose brick or stacked materials. Brace all angles and leave no gaps along the floor through which a tool or foot could slip.

General guidelines for erecting and using scaffolds are:

1. Design and build scaffolds to support four to five times the weight you anticipate holding on the scaffold. *Do not overload* the scaffold.
2. Always build scaffolds on firm, solid surface. Use only quality material that has not weathered or been weakened. For example, use long grain wood for flooring. Brace all angles and use an adequate number of supports.
3. Inspect structure of scaffold each day. Clean scaffold of debris and tools each day. Do not store materials on scaffold.
4. Place guard rails and toe boards on any platform above 10′ in height.
5. Overlap plank flooring at least 12″ and never extend a plank more than 12″ - 18″ beyond the end support. Usually planks should rest on supports every 6′ to 8′.
6. Protect and mark scaffolding so that vehicles and equipment moving materials do not hit the structure.
7. Fasten ladders to structure so they cannot slip or fall. When nailing braces and supports, always drive the nails home. Further, when possible, use cut nails to increase holding power.

The specific guidelines for erecting pole scaffolds are:

Light Trades Pole Scaffolds*

Specifications

1. *Uprights.* For heights not exceeding 32′ use 2″ x 4″ lumber or heavier. For heights above 32′ use 4″ x 4″ lumber or heavier.
2. *Ledgers.* Use two 1″ x 6″ boards nailed to either side of uprights, or one 1″ x 8″ board.
3. *Ribbons.* Use 1″ x 6″ board or heavier.
4. *Handrail.* Use 1″ x 6″ board, 1″ x 8″ board or 2″ x 4″. Place 42″ above platform and inside of upright.
5. *Platform.* Use two 2″ x 10″ planks. Overlap at least one foot.
6. *Toe-Board.* Use 1″ x 6″ board, or wider.
7. *Crossbracing.* Use 1″ x 6″ lumber or heavier.
8. *Footblocks.* At least 2″ in thickness.

*From *Manual of Accident Prevention in Construction.* Washington, DC: The Associated General Contractors of America, Inc., 1949.

Heavy Trades Pole Scaffolds*

(Bricklayers, Stonemasons, Concrete Workers, Steel Workers, Etc.)

Specifications

1. *Uprights.*
   a. For heights not exceeding 32′ use 4″x 4″ lumber or larger.
   b. For heights from 32′ to 72′ the first 32′ should be not less than 4″ x 6″ or larger.
   c. Splices on uprights to be at least two 1″ x 6″ pieces 30″ long. Splices to be nailed on all four sides of uprights.

2. *Ledgers.* Use two 1″ x 6″ boards or larger nailed or bolted to either side of upright or one 2″ x 6″ board.
3. *Ribbons.* Directly under ledgers, one 1″ x 6″ board or larger. Where ledgers are bolted, ribbons may be placed lower.
4. *Handrail.* Use 1″ x 6″, 1″ x 8″, or 2″ x 4″.Place 42″ above platform and nail on inside of upright.
5. *Platform.* 2″ planks not less than 10″ wide laid closely together. Planks to overlap at least 1′. Platforms to be 4′ in width.
6. *Crossbracing.* Use 1″ x 6″ lumber or larger.
7. *Footblocks and Sills.* Use not less than 2″ x 6″. When uprights rest upon pavement or sidewalk, the sill should be continuous.
8. *Toe-Board.* 1″ x 6″or wider.
9. *Side Screens.* If the material on the platform is piled higher than the toe-board one or more intermediate back rails should be added and ½″ wire mesh or its equivalent should be provided between the top railing and the toe-board.
10. *Concrete Buggies.* Where concrete buggies are to be used on a scaffold, it should be designed to support a concentrated load of 500 lbs. on ledgers and planking, in addition to the normal scaffold loading.

*From *Manual of Accident Prevention in Construction.* Washington, DC: The Associated General Contractors of America, Inc., 1949.

Additional Information

For additional information about safety in use of ladders and scaffolding, you may wish to read:

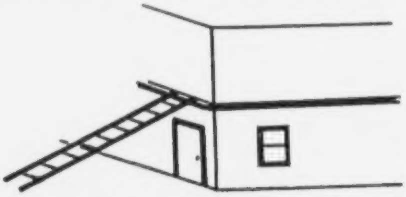
"Ladder and Scaffolding Safety" in the *Safety and Health Series.* Waco, TX: Center for Occupational Research and Development, 1982.

Manual of Accident Prevention in Construction. Washington, DC: The Associated General Contractors of America, Inc., 1949.

Self-Test Exercises

Read and answer the following questions. Check your answers with those in the Appendix. If you answer the items correctly, go on to the next chapter. If not, repeat your work in this chapter.

1. Critique the placement of the ladder in the figure below.



2. What are the specifications for using nails in scaffolding?
   Answer: ____________________
3. What means are available for securing a ladder at its base?
   Answer: ____________________

5. Using Protective Devices And Clothing

Introduction And Objectives

There are many cases where hazards cannot be removed from the job. A construction supervisor cannot remove the possibility of a worker stepping on a nail or getting bumped on the head with a beam. Similarly, the sparks and glare cannot be eliminated from the arc welder's job. In these and other instances, a worker must be protected against dangers with special protective equipment or clothing.

It is your employer's responsibility to assure that you are protected against hazards. But you also are responsible for wearing protective equipment as directed. That is the law. This chapter will introduce you to the types of protective equipment used on various jobs. After completing the chapter, you will be able to:

1. Recognize situations where protective equipment or clothing is needed to work safely.
2. Explain the hazards of not using protective devices or clothing properly.
3. Identify some of the types of protective clothing and equipment that are available for use.

Principles, Examples And Applications

Head Protection

An injury could occur to your head from a falling object, such as a tool or brick on a construction site. You could cut or bruise your head by bumping into a suspended object in an auto shop or many industrial settings. Other ways you can injure your head on the job are from shock, chemicals or burns. Because of the numerous hazards to your head and the seriousness of head injuries, workers in many jobs are required to wear protective headgear.

Hats and caps are available to protect your head, face, scalp, neck and hair. Some typical hard hats are pictured in Figure 3. The hats have straps that suspend the hat above your head. This suspension protects you from falling or moving objects by spreading the force over the entire area of your head. Hats can also be fitted with shields to protect the face, liners for work in cold weather, and chin straps to hold them securely in place. Aluminum hats are lighter than plastic, but do not protect as well against high impact. Hats with metal in them also do not protect against electric shock or some corrosive materials. Fabric caps are available that protect hair from dust, oil, sparks or from getting entangled in equipment. If you have long hair, this is an important consideration.

Inspect your hat each time you put it on. Make sure that the hat is suspended at least one and one-fourth inch above your head. Check the hat and the straps for cracks and wear, such as loose rivets, worn seams, or torn materials. You can wash most hats with warm, soapy water; then rinse and dry. Follow manufacturer's directions in using solvents to remove paint or other materials. Replace the sweatband as it becomes worn.

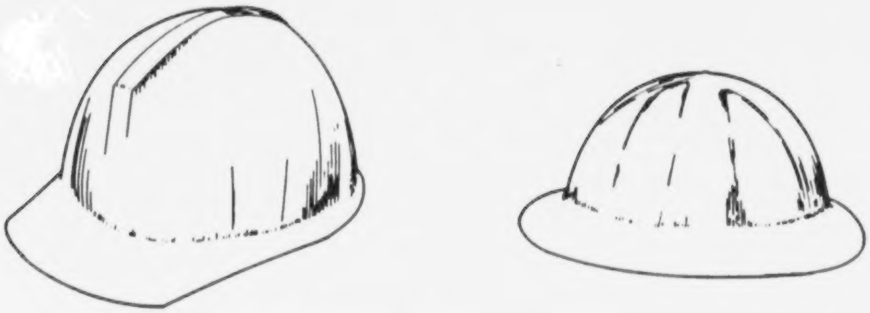
Eye And Face Protection

Eyes are particularly vulnerable to injuries in a shop or laboratory. Dust, wood or metal splinters, or other particles can become imbedded in the eye. Heat or chemical splashes can cause burns. Any of these hazards or blows to your eyes can cause permanent damage or even blindness. Because of the severity of accidents involving your eyes, wear eye protection even where the risk is slight. Eye protection should be worn at all times in the shop or laboratory and in many industrial settings. Contact lenses should *not* be worn where there is any risk of eye injury.

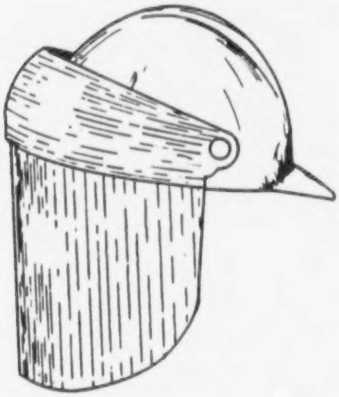
A number of different types of eye protection are available depending on the hazards you are exposed to. Some of these are pictured in Figure 4.

Safety Glasses

Safety glasses are similar in looks to regular eye glasses, but are designed with impact-resistant lenses and frames. They also are available with side shields, which protect against hazards from the

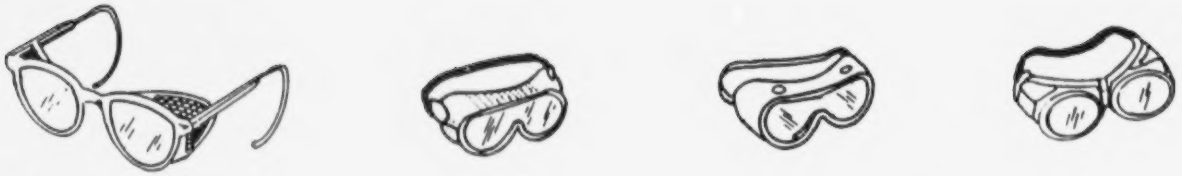


Plastic Cap **Aluminum Hat**

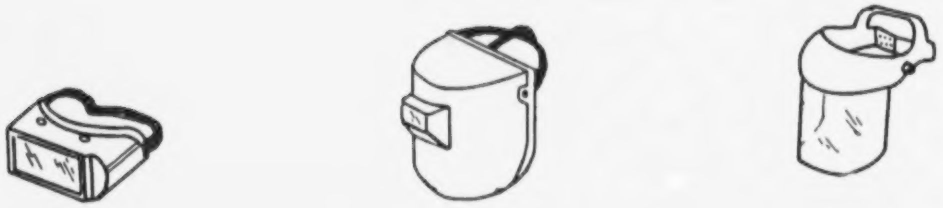


Protective Hat with Face Shield

Figure 3: Protective Head Equipment



Safety Glasses **Goggles** **Laboratory Goggles** **Chipping Goggles**



Welding Goggles **Welding Helmet** **Face Shield**

Figure 4: Face and Eye Protective Equipment

side. In most cases, glasses with side shields should be worn. Do not use glasses with clip-on side shields, because they easily can become detached.

Safety glasses protect against flying particles, such as dust, wood and metal slivers and other abrasives. If exposure is not too severe, they can be used for the following operations:

- Chipping
- Grinding
- Machining
- Spot welding (with tinted lenses)

Goggles

Goggles come in a number of forms to suit different eye protection needs. Standard goggles are made of a flexible or rigid plastic with a strap to hold them in place over your eyes. They have holes in the plastic for ventilation, since goggles do tend to fog up. The lenses also can be cleaned with defogging agents to help stop this problem.

Like safety glasses, goggles protect against flying particles in chipping, grinding, machining and spot welding operations. They provide somewhat more protection than safety glasses since they cover more of your face with no gaps. Goggles have the added advantage of being able to be worn over prescription eye glasses. However, they are not as comfortable as safety glasses, and become warm and steamy in a hot or humid environment.

Laboratory goggles differ from the standard shop goggles in that they have hooded ventilation. This allows air to circulate while preventing dangerous chemicals to enter through ventilation holes and cause injuries. Laboratory goggles should be worn in the laboratory or when handling chemicals. They protect against hazards such as chemical splash, acid burns, fumes which affect the eyes and glass breakage or other flying particles.

Chipping goggles give added protection against flying particles when the risk is severe, such as in some chipping and heavy grinding operations. They have contoured rigid eye cups which fit closely to the face. You can choose from two designs — one to wear over eye glasses and one to wear without eye glasses.

Welding Eye Protection

Both styles of chipping goggles can be used for acetylene burning, cutting and welding, *when fitted with tinted lenses.* This type of eye protection also can be used in furnace operations or working with molten metals. Specialized welding goggles, with a tinted plate lens as pictured in Figure 4, are also available for these operations. Welding goggles protect against sparks, harmful light rays, molten metal, flying particles, glare and heat.

Welding helmets offer the added protection required for arc welding. It is also recommended that you wear tinted safety glasses or goggles under the helmet. The helmet provides protection against sparks, intense light rays and molten metal.

Be sure to check with your supervisor that you have the correct type of filtered lens for the job you are on. Different types of welding, as well as the flux used and amount and temperature of the molten metal, emit different types of harmful rays. It is very important that you use the proper filter to protect your eyes against the hazards of the particular situation.

Face Shields

Face shields are shields connected to a head band to protect the face. They can be made of clear or tinted plastic, wire screen or a combination of materials. Generally, they are designed to flip up for close inspection of your work or when protection is not needed.

Face shields are used in combination with eye protection in a job where your face also is at risk. They can be designed to protect the crown or chin. This could be a situation where there is danger of splashing caustic materials and burning your face. Likewise, in heavy grinding or machining operations where flying particles could cut or bruise your face, a face shield is advised. They also can provide added protection against molten metals and sparks. Be sure to always wear eye protection behind the face shield.

Ear Protection

Your ears are vulnerable to a number of job hazards, most notably noise. If noise on the job is very loud, you feel pain and want to protect your ears. Noise of lower intensity can be dangerous also, even though the only thing you might feel is irritation because of the noise or being unable to communicate with co-workers. If you are exposed to the noise for long enough, it can cause temporary or permanent hearing loss. It can affect other parts of your body, too. Noise can cause nausea and reduced muscular control. This makes it difficult for you to perform your job well and could lead to an accident if your coordination is affected.

Devices are available to protect against noise and other hazards, such as flying particles, sparks or receiving a blow to the ear. There are two types of ear protectors, as shown in Figure 5. Ear plugs, which you insert into your ear canal, protect primarily against noise. Ear muffs protect against noise and impact.

Researchers have determined safe levels of exposure to noise. This is described in Table 3 as the number of hours per day you can be exposed to different sound levels without being injured. Decibels measure sound level or loudness, and can be determined using a sound level meter.

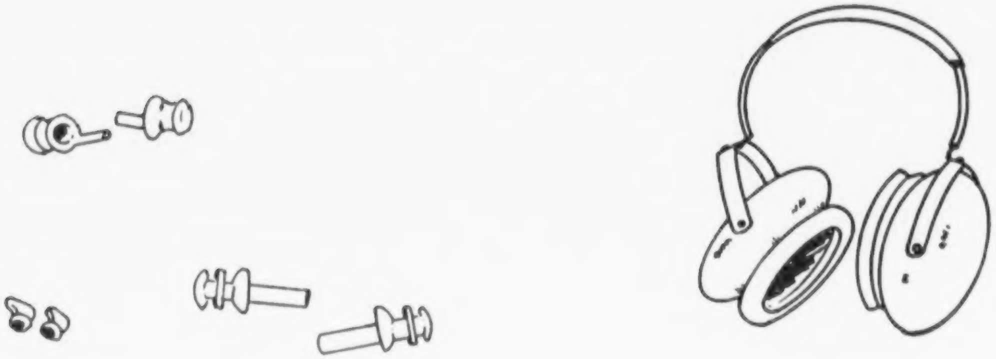
Ear protectors reduce the sound level to which you are exposed. Ear plugs, made out of rubber, plastic, or wax, can reduce the exposure by 25-35 decibels, depending on the type. Muffs can give 30-40 decibels of protection. Manufacturers report how much protection their equipment provides. Some guidelines for using ear protectors are:

- Choose a protector that is comfortable to wear and that provides adequate protection against noises in your work situation.
- Make sure they fit properly or you will not be getting the protection you should be.
- Wear them. If you do not wear the protectors all of the time, your protection is reduced substantially, much more than you would think.
- Do not over protect yourself. Often, you need to hear warnings or other information to perform your job properly and to avoid accidents.

Safety Clothing

Clothing offers protection on the job from such hazards as heat or cold, fire, dirt, chemicals, oils, and flying particles. In general, wear work clothing that is durable, comfortable, close-fitting and clean. Wear pants without cuffs and be sure they cover the tops of your shoes so that abrasive or caustic materials do not fall in your shoes. Specialized clothing may be required to protect against hazards in particular jobs:

- Flame retardant clothing — hot metal, sparks, flames.
- Short sleeves — hazards from working with power tools, equipment.
- Leather aprons or garments — heat, hot metal, impact, radiation.
- Plastic or rubber aprons or garments — chemicals, moisture, caustics, solvents.
- Metal reinforced aprons — blows to abdomen.



Ear Plugs

Ear Muffs

Figure 5: Ear Protective Equipment

Table 3: Safe Exposure to Noise**

Duration Per Day (Hours)	Sound Level (Decibels)
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼	115*

*No safe exposure over 115 decibels.

**Standards of the National Institute for Occupational Safety and Health.

- Knee, shoulder, elbow, back pads — abrasions or bruises.
- High visibility clothing — hazards from working near highways, runways, large equipment or at night.

Gloves

Gloves may be required to protect your hands from job hazards. There are a number of different types of gloves (Figure 6) which you should wear depending upon the hazards you are exposed to, the finger dexterity or sensitivity you need to perform tasks and the areas of your hands and arms that need to be protected. The types of gloves appropriate for various work situations are listed below:

- Light work — canvas, cotton
- Handling abrasive materials — leather or reinforced light weight gloves
- Handling corrosive materials or oils — plastic, rubber
- Handling hot materials — leather, loop pile, aluminized, asbestos
- Welding — leather, gauntlet gloves

Do not wear gloves when working with machinery having moving parts.

Shoes

Safety shoes are designed to protect feet from falling or rolling objects, slipping, heat, spills, or shock. Often they are supplied by or through the company and are an important part of protecting yourself against injury. Depending on your work situation and company policy, select boots or shoes with any of the following design characteristics:

- durability
- acid resistance
- oil resistance
- nonconductivity
- conductive (to drain static)
- nonsparking
- nonslip
- cushioned soles
- heat resistance
- impact resistance (steel toes, instep protectors)
- puncture resistance (steel insole)

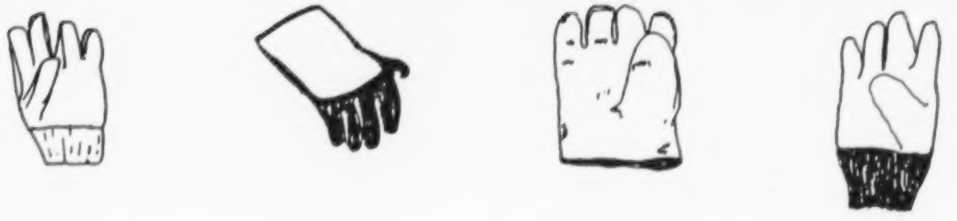
Some typical safety shoes are pictured in Figure 7.

Respiratory Protection

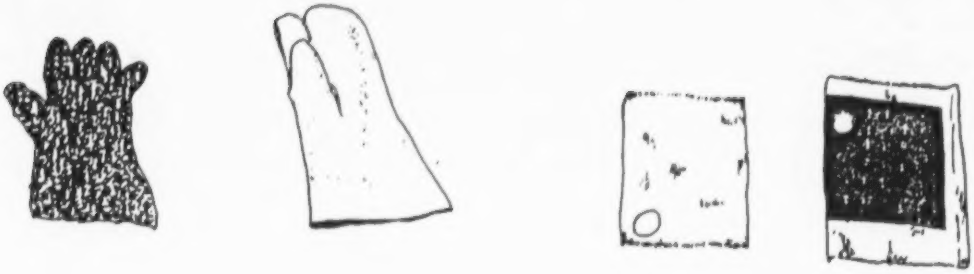
Respirators protect your lungs from particle-laden or toxic air which could cause temporary or permanent injury, disease or death. This could mean protecting you from a shop with too much dust in the air or providing you breathable air to work in an oxygen-deficient environment. Respirators also can be used to filter out certain toxic gases or particles.

Respirators fall into two major categories:

1. *Air purifying respirators.* Through filters or chemicals, these respirators remove toxic materials from the air. They are *not* for use where there is not enough oxygen in the air.
2. *Air supplied respirators.* These respirators provide breathable air to the user. They are for use in an oxygen-deficient environment (such as space) or situations with high concentrations of moving particles (abrasive blasting).

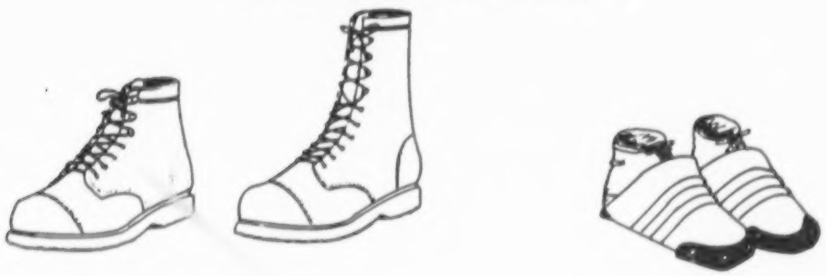


Cotton Work Glove **Reinforced Cotton Glove** **Leather Glove** **Plastic Glove**

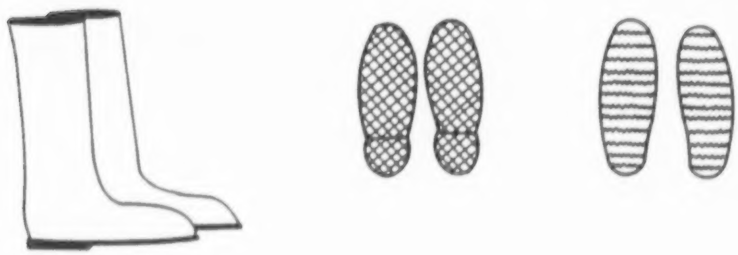


Loop Pile Glove **Welding Glove** **Palm Pads**

Figure 6: Gloves and Hand Protectors



Steel-Toed Shoe and Boot **Instep Protectors**



Rubber Boots **Steel-Lined Soles** **Crepe Soles(Non-Slip)**

Figure 7: Safety Shoes

If you have a need for a respirator, it will most likely be the first type, the air purifying respirator. These are used for activities such as spray painting, welding, using solvents, blasting, or sanding. Different types of air purifying respirators protect against different hazards. Be sure that you have the appropriate respirator for the job and that you are properly trained in its use. Check with your supervisor or with the equipment manufacturer to be sure. Otherwise, you may *not* be protected from serious dangers.

Three types of air purifying respirators are pictured in Figure 8. Also pictured is a dust mask, which protects against breathing dust or fiber particles. The uses of the different protectors are summarized in Table 4.

Table 4: Breathing Protectors

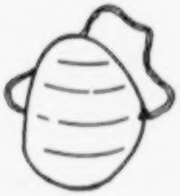
Protector	Sample Applications	Hazards Protected From
Dust Mask Particulate Respirator	Wood working Construction Brake work Blasting	Dust Fibers Wood/metal particles **Not** for dangerous fumes or lack of oxygen
Chemical Cartridge Respirator	Nonemergency situations Parts cleaning Welding Spray painting Working with chemicals	Organic vapors (carbon tetrachloride, gasoline, benzene, ether Dust, fog, smoke in combination with vapors Ammonia gas Mercury **Not** for carbon monoxide or lack of oxygen
Gas Mask	Emergency situations — more hazardous than those above, short-term use	Organic vapors Acid gas Ammonia gas Carbon monoxide Dust, fog, smoke in combination with gas or vapor **Not** for lack of oxygen

Additional Information

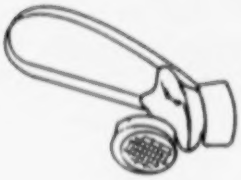
More information on protective equipment is contained in standards of the American National Standards Institute and the National Institute for Occupational Safety and Health. You may also refer to the following document:

National Safety Council. *Accident Prevention Manual for Industrial Occupations, Seventh Edition.* Chicago: National Safety Council, 1974.

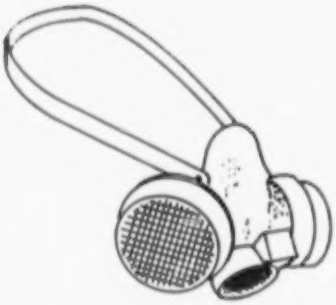
Two sources that you should not overlook in being sure that you are using the proper equipment and using it correctly are your job supervisor and equipment manufacturers.



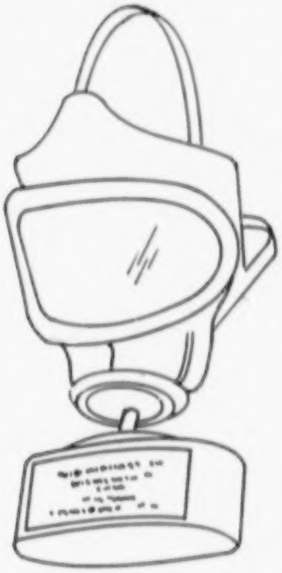
Disposable Dust Mask



Particulate Respirator



Chemical Cartridge Respirator



Gas Mask

Figure 8: Breathing Protectors

Self-Test Exercises

Read and answer the following questions. Check your answers with those in the Appendix. If you answer less than 7 items correctly, repeat your work in this chapter. If you score 7 or 8 correct answers, go on to the next chapter.

1. What are two hazards that are reasons for wearing a safety hat?
   a. ______________________________
   b. ______________________________
2. When should you wear a face shield?
   Answer: ______________________________
   ____
3. What are two sources of information on the proper uses of and how to use safety equipment?
   a. ______________________________
   b. ______________________________

   List the type of equipment or clothing required for the following tasks:
4. Cleaning a magnetic head with carbon tetrachloride. ______________________________
   ____
5. Operating a jack hammer. ______________________________
   ____
6. Operating a lathe. ______________________________
   ____
7. Carrying steel beams. ______________________________
   and ______________________________
8. Inspecting a construction site. ______________________________
   ______________________________ and ______________________________

6. Appendix

Answers to Self-Text Exercises

Chapter 3: Using Tools and Equipment Safely

1. Moving parts and electrical shock.
2. Any three of the following: wet environment; no ground connections; improper size fuse; damaged insulation; tool not double insulated.
3.- Any three of the following items: motor operation; guards in place and working; clean,
5. lubricated and sharpened; conditions of parts; controls; work head; and parts.
6. Develop awareness of risks and hazards.
7. Learn to operate, adjust and maintain tools and equipment safely.
8. Be alert.

Chapter 4: Using Ladders and Scaffolding Safely

1. Strengths: Ladder does not appear to be defective as a tool.
   Limitations: Angle of base is too great (or base is too far from wall); not enough overhang at top; there is no visible securing of base of ladder; the ladder is placed in front of door.
2. Drive nails home and use cut nails where possible.
3. Safety feet; nailing; tying; butting against cleat; holding ladder.

Chapter 5: Using Protective Devices and Clothing

1. Any two of the following items: falling objects; suspended objects; shocks; chemicals; burns.
2. When your face is in danger from flying particles, caustic materials, molten metals or sparks.
3. a. Job supervisor.
   b. Equipment manufacturer.
4. Chemical cartridge respirator
5. Ear protector (plugs or muffs)
6. Eye protector (safety glasses or goggles)
7. Instep protectors and gloves or palm pads
8. Hard hat and safety shoes. Depending on the operations, eye protectors may be required.

Posttest

***Directions:** Answer the following questions. After completing all questions, check your answers with the answers that follow. If you score 90% or better, you have completed successfully Basic Safety II. If you score less than 90%, repeat the portion of the module with which you had difficulty.*

1. The major cause of injury associated with moving materials is:
   a. scraping knuckles because of load size, whether carrying a load or using a hand truck.
   b. having a load shift and fall, either smashing toes or straining muscles.
   c. abrasions caused by snagging clothing on moving equipment like conveyors.
   d. trying to lift too heavy a load and straining back.

2. List in order the steps in moving a load manually:
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________
   f. ______________________________
   g. ______________________________

3. Why is it important to crouch or squat when picking up or placing an object on the ground:
   Answer: ______________________________

4. Stacked sacks of materials should never be piled above how many layers? Answer: ______________

5. What five things should you check before lifting a load to move?
   a. ______________________________
   b. ______________________________
   c. ______________________________
   d. ______________________________
   e. ______________________________

6. List three safeguards against electrical shock from power tools and equipment:
   a. ______________________________
   b. ______________________________
   c. ______________________________

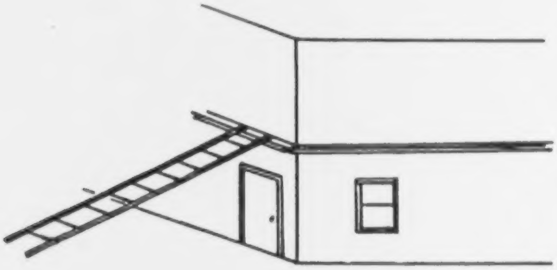
7. Why should you always put tools away in a proper storage place when finished with them?
   Answer: ______________________________
   ____
   ____

8. Which of the following is *not* a safety guideline for using tools and equipment:
   a. Maintain tools and make minor repairs as directed by your supervisor or manufacturer's instructions.
   b. Keep power cords off the floor by coiling and hanging on a nail on the wall.
   c. Transport tools in a box, cart, belt or pouch.
   d. Use a tool with a proper size and duty rating for the job.

9. What is the purpose of machine guards?
   Answer: ______________________________
   ____

10. List three steps to develop safety skills in working with tools and equipment:
a. ____________________
b. ____________________
c. ____________________

11. Examine the following picture and point out the safety hazards that are illustrated.
12.



13. What is the general rule for overlap of extension ladders?
Answer: ____________________

14. Scaffolds should be designed and built to support at least ______ times the weight they are expected to hold.

15. Guard rails and toeboards should be used on all scaffolds. OSHA standards require that they be used on structures above how many feet?
Answer: ____________________

16. What special clothing or equipment is required for arc welding?
Answer: ____________________, ____________________, and ____________________.

17. How do laboratory goggles differ from shop goggles?
Answer: ____________________

18. What sound level in decibels is safe for a worker to be exposed to for 8 hours per day?
Answer: ____________________

19. List three hazards that safety shoes are designed to protect against:
a. ____________________
b. ____________________
c. ____________________

20. When would you need a particulate respirator?
Answer: ____________________

Answers to Posttest

1. d
2. a. Size-up load to determine approximate weight and most desirable lift point.
   b. Assume comfortable position with feet close to load and slightly staggered.
   c. Crouch or squat close to load with knees bent and back straight.
   d. Grasp load securely, take and hold deep breath and tuck chin.
   e. Rise slowly, lifting the load by straightening your legs with stress on legs and shoulders.
   f. Hold load close to body with weight evenly distributed.
   g. Return load to floor or platform in similar fashion to that of picking-up load.
   (Count 1 point for first 3 items and a second point for remaining 4 items. Total of 2 points.)
3. The idea is to make your leg and shoulder muscles do the work, *not* your back.
4. Ten layers high
5. a. Hands, arms and shoes for moisture and grease
   b. Materials for jagged and sharp edges
   c. Surface of floor for rough, slick or uneven areas
   d. Area through which to carry load for clearance
   e. Spot where load will be placed for debris
   (Count 1 point for first 2 items and a second point for remaining 3 items. Total of 2 points.)
6. a. Ground wire
   b. Low voltage
   c. Double insulated construction
   (Count 1 point for first items and 1 additional point for next 2 items. Total of 2 points.)
7. They could be used by an untrained worker. They could get in someone else's way.
8. b
9. To protect the worker from mechanical hazards.
10. a. Develop an awareness of the risks and hazards.
    b. Learn to operate, adjust and maintain tools and equipment safely.
    c. Be alert.
    (Count 1 point for first correct answer and a second point for the next 2 items. Total of 2 points.)
11. a. base is too far from wall (angle is not great enough);
12. b. extension above wall is too small (less than 36");
    c. ladder in front of door;
    d. the base of the ladder is not secured;
    e. the bottom is not barricaded or identified.
    (Score 1 point for getting 3 or 4 correct; score 2 points for getting 5 correct.)
13. About 10 percent of the height of the extension ladder is included in the overlap therefore, 3′ on a 36′ ladder; 4′ on a 40′ ladder and 5′ on a 48′ ladder are in the overlap.
    (Count 1 point for 1 length and a second point for all 3 lengths. Total of 2 points.)
14. 4 to 5 times the anticipated weight

15. 10′
16. Welding helmet, gloves and apron
17. The ventillation on laboratory goggles is hooded so that caustic materials cannot enter.
18. 90 decibels
19. Any three of the following:
    a. Falling or rolling objects
    b. Slipping
    c. Heat
    d. Spills
    e. Shock
    (Count 1 point for first correct answer and 1 point for next 2 correct. Total of 2 points.)
20. When the air is laden with irritating particles such as dust; fibers; wood, metal, or stone particles.

Competency:

1. Demonstrate safe and effective use of typical hand and power tools used in the trade.

Instructional Objectives:

1. Identify safe practices for the use of common hand tools used in the trade.
2. Identify safe practices for the use of common power tools used in the trade.

Learning Activities:

1. Read Hand Tool Safety Information Sheet.
2. Read Power Tool Safety Information Sheet.
3. Complete the Hand Tool Safety Self-Test.
4. Complete the Power Tool Safety Self-Test.
5. View the videotape "Electronic Tool Catalog" (Wheeler Manufacturing Corporation).

Application Exercises:

1. Demonstrate the safe use of a stationary grinder.
2. Demonstrate the safe use of a portable grinder.
3. Demonstrate the safe use of a metal-cutting band saw.
4. Bevel pipe with a grinder
5. Cut, ream, and thread pipe with a threading machine.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on the job. A list of the application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. A copy of the information sheets, self-test questions and answers, and test and answers is included with this unit.

Audio-Visual Materials:

1. The videotape "Electronic Tool Catalog" is available from Wheeler Manufacturing Corporation, P. O. Box 688, Ashtabula, Ohio 44004, (216) 998-2788. Contact Dick Mazzola or Marty Oppenheimer. The videotape shows Wheeler tools in operation including pipe cutters and threaders. Literature on Wheeler tools will accompany the tape upon request.

Resources:

1. Books:
   - A. Tools and Their Uses. Washington, D.C.: Naval Education and Training Command, NAVEDTRA 10085-B1, 1984. This book presents a comprehensive review of hand tools, power tools, measuring tools, grinding operations, and metal cutting operations. It is available from the U.S. Government Printing Office, stock ordering No. 0502-LP-050-4255. There is a branch office in Milwaukee.

2. Audio-Visual Materials:
   - A. "Hand Tools 1 and 2" and "Power Tools" videotapes are available from NUS Training Corporation.
   - B. "Hand Tools" cassette/tape is available from NAPHCC LaBelle Lending Library, P. O. Box 6808, Falls Church, VA 22046. Order P-020.
   - C. "Power and Hand Tool Safety" videotape is available from Tel-A-Train, Inc.
   - D. "Basic Hand Tools" videotape is available from Marshall Maintenance Productions.
   - E. "Hand Tools" videotape is available from Industrial Training Corporation.
   - F. The following videotapes are available from the National Association of Plumbing, Heating, and Cooling Contractors, P. O. Box 6808, Falls Church, VA 22046.
     - "Rigid Products" illustrates how wrenches, threaders, pipe and tube cutters, vices, hoists, torches, saws, and benders are used.
     - "Rigid Pipe and Bolt Threader" demonstrates the use of the Rigid 535 Pipe and Bolt Threading Machine.
     - "Hand Treaders by Ridge Tools" provides a step-by-step description of how to thread pipe.

Hand Tool Safety Information Sheet

This module covers the safety procedures for properly handling and maintaining the most common hand-powered tools. Since the use of tools enables workers to carry out the most important functions of their jobs, each worker must know how to use his or her tools as safely and as efficiently as possible. Obviously, all tools should be kept clean and free of grease or other substances which might affect the grip of the worker or might impair the tools' efficiency. Likewise, tools should not be thrown. In addition to possible worker injury, the tool might be damaged, as well.

This and the following pages contain specific rules for good safety practice. The tools have been grouped into categories for easy reference.

A. HAMMER SAFETY: claw, ball peen, blacksmith's, bricklayer's, setting, riveting, engineer's, stone sledge, mash, and upholsterer's.
   1. Choose the correct type and size hammer for the job.
   2. The hammer face should be about 3/8" larger in diameter than the object being struck.
   3. Never strike two hammer faces together; the faces may chip off.
   4. Strike the object squarely and flatly to prevent slipping or denting.
   5. If the tool's handle is damaged replace the handle.
   6. If the hammer face is damaged or worn out replace the entire hammer.
   7. Use a sledge to drive hardened cut and masonry nails, not a claw or bricklayer's hammer. This can damage the faces of the latter two and may cause dangerous flying pieces.
   8. Do not use hammers on wooden or plastic handled chisels. Hammers will ruin these handles and may injure hands.
   9. Do not pound with the cheek (side) of the hammer. It can too easily slip off and also will damage the handle.

B. MALLET SAFETY: wood, plastic, rubber, rawhide, and non-ferrous hammers such as lead, copper, aluminum, and brass.
   1. Never use mallets for pounding on sharp objects or for driving nails. This will damage the soft heads.
   2. Use mallets to pound on wood or plastic handled chisels to prevent damaging the chisels.
   3. Do not use a mallet if the handle is loose, the head may fly off.

C. STRUCK TOOL SAFETY: cold chisels, all-steel wood chisels, drift punches and pins, star drills, blacksmith's punches, nail sets, wedges, and nail pullers.
   1. Be sure struck tools are ground at the proper angles, are sharp and have no burns.
   2. Remove mushroomed heads and properly dress the struck face to prevent flying pieces.

3. Replace worn out, cracked, or bent struck tools to prevent injuries.
4. Choose the correct struck tool for the job.
5. Hold the struck tools steady, but with a relaxed grip, so fingers or hands will not be hit. Use pliers or another tool if there is a hand injury hazard.
6. Tools being struck by other workers should be held with tongs.
7. Protect sharp edges when tools are stored, to prevent damaging them or cutting your hands or fingers.

D. SCREWDRIVER SAFETY: regular, Phillips, Reed and Prince, and electrician's in all their shapes and sizes.

1. Select the correct screwdriver for the job with the correct tip style and size, the correct length and shank, the correct handle size, smaller diameter for more speed, larger for more torque.
2. Never pound on a screwdriver. This will ruin the handle, damage the tip, and bend or break the shank.
3. Do not hold the screw with your hand while driving it, drill or punch a pilot hole to prevent hand or finger injuries.
4. Keep hands and fingers out from under the screwdriver to prevent gashes if it slips.
5. Screwdrivers should not be used as pry bars; this will bend or break the shank and damage the tip.
6. Never use pliers to help turn a screwdriver, the job teeth will ruin the shank or handle.
7. Use an appropriate wrench only on heavy-duty, square-shanked screwdrivers.
8. Use a screw-holding clip or magnetized screwdriver to start screws in awkward places and to avoid hand or finger injury.
9. Use non-sparking screwdrivers, usually made of beryllium copper, when working near explosive vapors.
10. Use only properly insulated screwdrivers when working on electrical devices.
11. Do not use a screwdriver for electrical testing, this will burn or blast a piece out of it.
12. Do not use a screwdriver for stirring paint, varnish, or other materials that will leave a coating on it.

E. WRENCH SAFETY: open-end, box, socket, adjustable, pipe, monkey, chain, spanner, tee, torque, and Allen.

1. Select the right type of wrench for the job. Box and socket are usually the safest.
2. Select the correct size wrench for the job, considering fit and leverage needed. A snug fit is necessary. Don't use cheater bars as the force of the additional leverage will exceed what the wrench handle was designed to withstand.
3. Pull on adjustable wrenches, putting the force on the fixed jaw.
4. Be sure the wrench fits squarely on the object and is not tilted. This will help prevent slipping off or damage to the wrench and object.
5. Be sure your footing and your stance is adequate to prevent falling if something should let loose unexpectedly. Brace

yourself if necessary.

6. Use a straight handle rather than an offset if possible, as there is less chance of slipping.
7. Never pound with a wrench.
8. Use penetrating oil on a frozen object first. If this does not loosen it, use a heavy-duty wrench that has a striking face (made to hit with a hammer).

F. PLIERS SAFETY: regular, slip-joint, pump, long nose, needle nose, side cutters, lineman's, crimpers, hose clamp, wire stripper and glass cutters.

1. Select the correct size and type for the job.
2. Never use a cheater on pliers as it can bend, break, and ruin them.
3. Do not expose pliers to excessive heat as it will draw the temper out.
4. When cutting, cut at right angles to the wire. This puts the least strain on the pliers.
5. Do not bend the wire back and forth against the cutting edges as it may damage the edges or spring the pliers.
6. When cutting, point the open side down so the cut end will not fly out at someone.
7. Put a drop of oil on the pliers joint to lengthen its life and allow for easier operation.
8. Use only pliers with high dielectric insulation (not just plastic-dipped ones) when working on electrical devices to prevent shocks or electrocution.
9. Keep jaw teeth or knurls clean to avoid slips and damage to material surface.
10. Never use pliers as a hammer.

G. VISE SAFETY: utility, machinist's, woodworker's, pipe and drill press.

1. When working on an object held in a vise, work as close to the vise as possible. This will help eliminate vibrations and chances for slipping.
2. Clamp objects in the middle of the jaw to prevent uneven strains on the vise.
3. Never use a cheater on a vise handle. This will bend the handle or ruin the screw.
4. Use a vise of adequate size. It is easy to ruin a vise by overloading it.
5. Be sure the vise is securely fastened to prevent it from falling off. Use all bolt holes and proper sized bolts.
6. Do not pound on vise jaws. They are hardened and may chip or crack.
7. Support the far end of long work to avoid putting excessive strain on the vise.
8. Repair or replace a damaged vise before using it.

H. CLAMPING TOOL SAFETY: bar, pipe, miter, spring, hand screw, "C", welder's, bank, and vise grips.

1. Select the correct size and type of clamp.
2. Keep all moving parts clean and lightly oiled to provide easy operation.

3. Do not over-tighten clamps and never use a cheater. This will bend, break, or ruin the threads.
4. Do not use clamps to secure scaffolding. If they are bumped they could let loose.
5. Never use clamps for hoisting materials. Use only approved devices.

I. SNIPS SAFETY: tin, aviation, combination, compound, lever, and shears.
1. Select the correct size and type snips for the job.
2. Keep snips sharp.
3. Do not cut wire with snips, it will damage the cutting edges. Use only on non-hardened sheet metal.
4. Use only hand pressure on the handles, never a hammer or your foot. This could spring the hinge.
5. Protect the edges and points of snips when stored to prevent injury and damage.
6. Wear gloves when cutting with snips.

J. SAW SAFETY: hand saws, miter box, keyhole, compass, hack, back, dovetail, and coping.
1. Select the correct type and size saw for the job.
2. Keep saws sharp and set to insure good cutting.
3. Protect the points from being damaged by checking for nails, bolts or grit before sawing.
4. Use a saw-horse or bench, not your knee or leg to hold material when sawing.
5. Make sure saw handle is in good condition and tight.
6. Be aware of hand, finger, and leg position when sawing to prevent personal injury.
7. Wear gloves when sawing metal to prevent being cut by sharp cuttings.
8. Hacksaw teeth should point away from the handle and saw strokes directed away from yourself.

K. FILE AND RASP SAFETY: rough, coarse, bastard, second-cut, smooth and dead smooth metal files, cabinet files, wood rasps, other surform tools.
1. Select the proper type and size file for the job.
2. Do not confuse wood and metal files and rasps. Filing metal with a wood file or rasp will ruin it.
3. Cut on the forward stroke.
4. Clean files often while using to prevent slipping and to insure good cutting.
5. All files must have handles of proper size to prevent hand wounds.
6. Clamp objects to be filed securely to prevent filing your hand or fingers.
7. Never use files or rasps as pry bars, they are very hard and brittle and will snap, besides damaging the teeth.

Reference:

1. Related Training Modules for Stationary Engineer. Eugene, Oregon: Lane Community College, 1982.

Hand Tool Safety Self-Test

Select the answer which best completes the statement. Write the answer in the blank to the left of each statement.

1. _____ Hand tools should always:

   a. have a layer of grease to prevent rust during winter work
   b. have a layer of oil to prevent rust during winter work
   c. be kept clean of grease or oil at all times
   d. be covered with graphite during the winter

2. _____ The hammer face should be how much larger in diameter than the object being struck?

   a. 3/8"
   b. 5/8"
   c. 1" or more
   d. 1/16" only

3. _____ If a mallet handle is broken, you should always:

   a. tape the handle with non-ferrous tape
   b. glue and splice the handle
   c. heat the handle
   d. replace the handle

4. _____ The following is an example of a struck tool:

   a. star drill
   b. crescent wrench
   c. screwdriver
   d. needle nose pliers

5. _____ Tools being struck by others should be held with:

   a. gloves
   b. tongs
   c. cheater bars
   d. hoists

6. _____ On which type of screwdriver should a wrench be used?

   a. heavy-duty, square-shank
   b. star shanked titanium
   c. Phillips light weight
   d. none of the above

7. _____ Proper wrench safety always includes:

   a. oiling the handle
   b. tilting the wrench at an angle
   c. using an offset handle whenever possible
   d. using penetrating oil on frozen objects

8. _____ What type of cheater should be used with pliers?

   a. non-ferrous metal
   b. wood
   c. none
   d. spring steel

9. _____ When using a vise, objects should be clamped:

   a. at the near end of the jaw
   b. at the middle of the jaw
   c. wherever you want
   d. at the far end of the jaw

10. _____ Clamps should be:

   a. stored in a pile
   b. used for hoisting
   c. used for securing scaffolding
   d. tightened without the use of a cheater

Hand Tool Safety Self-Test Answers

1. c

2. a

3. d

4. a

5. b

6. a

7. d

8. c

9. b

10. d

Hand Tool Safety Test

Select the answer which best completes the statement. Write your answer in the blank at the left of the statement.

1. _____ Snips may be used to cut:

    a. wire
    b. non-hardened sheet metal
    c. all lead alloys
    d. hardened sheet metal

2. _____ Hacksaw teeth should be:

    a. pointed toward your body
    b. pointed away from your body
    c. bent at both ends
    d. heated before cutting

3. _____ One characteristic of a file or rasp is it's:

    a. brittle
    b. soft
    c. springy
    d. silver coated

4. _____ When working on or near electrical devices, use only pliers with:

    a. high dielectric insulation
    b. low dielectric insulation
    c. circuit breakers
    d. plastic handles, shanks, tips and barrels

5. _____ A cheater bar provides for:

    a. more leverage
    b. less leverage
    c. less foot-pounds-per-square-inch
    d. C-clamps

6. _____ Wrenches should always be:

    a. pulled toward your body
    b. pushed away from your body
    c. silver-plated
    d. none of these

7. _____ Struck tools with mushroomed heads should be:

    a. repaired
    b. used as often as possible
    c. used in conjunction with a sledge hammer
    d. coated with plastic

8. _____ When working near explosive vapors, screwdrivers should be:

- a. made of beryllium copper
- b. made of non-ferrous metals
- c. stored in dry ice prior to use
- d. steel-coated

9. _____ When moving about the job site, tools should be:

- a. tossed
- b. thrown
- c. carried
- d. coated in plastic

10. _____ Wood rasps and files should always:

- a. be used on steel
- b. be sharpened
- c. be rubber-tipped
- d. have the object clamped to be filed

Hand Tool Safety Test Answers

1. b
2. b
3. a
4. a
5. a
6. a
7. a
8. a
9. c
10. d

Power Tool Safety Information Sheet

This module covers safety procedures for the most commonly-used power-actuated tools used in the pipefitting trade. Many of the rules for operating these tools--as for the operation of hand tools--require only common sense. For example, every worker should know the following: electric tools must have grounding wires or insulated cases to prevent shock; electrical cords must be examined prior to use for insulation or prong damage; proper cord sizes should be used to prevent overheating and fires; plugs should be removed from receptacles carefully to avoid wire damage; switches should be in good operating condition and should be in "off" position before the cord is plugged in; adjust and clean power tools only when the tool is unplugged, and be cautious when plugging in a power cord for another worker.

ELECTRIC

PORTABLE CIRCULAR SAW SAFETY

1. Must be equipped with a fixed guard over the upper half of the blade and a working movable guard over the lower half.
2. Saw blade should clear the stock being cut by no more than 1/8 inch.
3. Use the recommended blade, the proper size, in good condition, and installed correctly.
4. Never block or tie the guard back.
5. Allow the saw to cut without forcing.
6. Check material to be cut for nails, grit, or any material that may interfere with cutting.
7. Always check for the lower guard return before putting the saw down.
8. Adequately support the material to be cut to prevent binding.
9. Allow the saw blade to come to full speed before cutting to prevent overloading and possible kickbacks.
10. Hold the saw firmly, do not allow it to pull out of your hands.
11. Saw in the forward motion only, never backwards.
12. Clean sawdust from around the movable guard often and before using to insure it works properly.
13. Do not over-reach.
14. Never try to cut a curve or other than in a straight line with a portable circular saw.

SABER SAWS AND RECIPROCATING SAWS SAFETY

1. Check electrically operated saws to see that they are grounded and that all electrical connections are safe.
2. Do not use electric saws or any electric tools while standing on damp ground or wet surfaces.
3. Make sure the electric cord cannot become fouled while using the tool.
4. Make sure the work to be cut is solidly supported.

5. Select the proper blade for the type of work to be done. Saber saw blades are of three types: woodcutting, metal cutting, and knife blade. Reciprocating saw blades are made in a variety of sizes and shapes.
6. Make sure the blade is locked securely before starting to work. In changing blades, follow the instructions found in the operator's manual which usually comes with each electric saw.
7. Rest the saw shoe firmly against the work when operating the saw or the blade may catch and the saw will move instead of the blade.
8. Move the saw forward rapidly enough to keep the blade cutting. Do not force the saw. Use the hand knob for safer control. Follow the line of cut accurately.
9. Check the saw for loose parts and screws. This will help to insure better work and safer operation.
10. Clean the saw periodically. Air inlet and outlet passages should be kept clean to insure a cool-running motor. Accumulated dust should be blown out of the motor frame with a low-pressure air jet.
11. Always disconnect the cord before repairing or adjusting the saw and before changing blades.

POWER HACKSAW SAFETY

1. Before using the saw, carefully read the operator's manual which came with it. Operate the saw at the speed recommended by the manufacturer.
2. Clamp the work securely in a saw vise. Clamp it so that the blade will not have to cut across the edge of thin sections. For example, clamp an angle iron with the corner up.
3. Use the right blade for the job according to the operator's manual.
4. Install the blade so that the teeth will point in the direction of cutting. Check the blade manufacturer's recommendations for the correct tension to put on a blade. Use a torque wrench to tighten the blade.
5. Make a notch with a file to start the blade on sharp edges.
6. Be sure the blade is up and out of contact with the work before starting the saw. After the blade is in motion, let it down gently on the work, holding up on the handle slightly to reduce the pressure while the blade is starting its cut.
7. Do not push down on the saw to add pressure to the blade while cutting. Use just enough pressure on the blade to keep it cutting. Reduce the pressure when cutting thin metal. Curly chips indicate correct pressure. Fine dust means the pressure is too light. Thick chips mean the pressure is too heavy.
8. Always stop the saw before making any adjustments.
9. Wear safety glasses. Keep your hands away from your eyes after working around a power hacksaw to prevent small metal chips from getting into your eyes.

METAL-CUTTING BAND SAW SAFETY

1. Wear safety glasses and keep your hands away from your eyes. Small pieces of metal rubbed into your eyes will cause pain and serious injury to your eyes.
2. If the saw teeth wear off unusually fast, reduce the speed of the blade. Sawing across the edge of thin stock may knock teeth from the blade.
3. Clean the blade brushes frequently in kerosene. Replace them when they are worn.
4. Keep the saw blade and all moving parts properly lubricated as directed by the operator's manual.
5. Keep your hands a reasonable distance from the blade when cutting.
6. Keep the adjustable blade guide as close as possible to the material.
7. Always keep the blade at the recommended tension when cutting.
8. Follow general safety rules applying to all power equipment.

STATIONARY GRINDER SAFETY

1. Wear a face shield or goggles for all grinding operations. Goggles and shields should be shatterproof.
2. Be sure that any shields on the grinder are unbroken, adjusted correctly, and clean.
3. Check and, if necessary, adjust tool rests before starting the grinder. Tool rests should be rigid, slightly above the center of the grinding wheel, and not more than 1/8 inch away from the face of the wheel.
4. Check the wheel for flaws and cracks. After a new grinding wheel has been installed, stand to one side and let the grinder run for a full minute. Do this also if you are unfamiliar with the grinder or if a piece of metal has been jammed into it, even though the wheel is not new. A defective wheel will usually break and fly to pieces during the first minute.
5. Grind only on the face of the wheel. Side pressure may cause the wheel to break and will put strain on the wheel bearings.
6. After the grinder is turned on, begin grinding only when the wheel has come up to full speed. Stop grinding before the grinder is turned off.
7. Do not make adjustments of the rests or other grinder parts until the wheel has come to a full stop.
8. Keep your fingers away from the wheel. Use pliers to hold small objects against the wheel.
9. Do not touch your face or eyes after grinding unless your hands have been thoroughly washed to remove abrasive dust and metallic particles. Severe eye injury may result from these materials being transferred from your hands to your eyes.
10. Keep grinding wheels dressed and trued. This requires a special tool. A dull wheel causes unnecessary heating. Do not use grinding wheels that are "out-of-round."
11. Do not slow down the speed of the grinding wheel by applying too much pressure to the work. This will reduce grinding efficiency, cause excessive heat buildup in the motor, and may cause excessive wear on the bearings.

12. Turn off the grinder and make adjustments immediately for any vibration that is noticed.

PORTABLE GRINDER SAFETY

1. Before you start the portable grinder, check to be sure that other workers are out of range and are wearing suitable eye protection.
2. Do not start or operate a grinder unless all safety shields are in place.
3. Do not lay the portable grinder down until it comes to a complete stop.
4. Stand in a balanced, comfortable position. Be sure you have good footing.
5. Hold the portable grinder firmly with both hands at all times.
6. Be careful to avoid entanglement with the attachment cord.
7. Check the grinder regularly for damaged parts or a cracked or glazed grinding wheel.

DRILL PRESS SAFETY

1. Use drills that are properly sharpened.
2. Check the drill to see that it is straight and has no nicks or burrs. A bent drill is difficult to control. To check for bent drills, start the drill motor and observe the drill point for trueness.
3. Never operate the drill with a loose chuck. Tighten the drill in the chuck firmly with a chuck key.
4. Check to see that the chuck key is removed before starting the drill press.
5. Avoid wearing loose clothing when operating the drill press.
6. Keep the floor around the machine free from scrap material, oil, and grease. A safety zone with well-marked lines should surround the drill press.
7. Select the drilling speed that is suitable for the work being done.
8. Wear goggles or other eye protection.
9. Be sure that main power switch is "OFF" when setting up or making adjustments on the drill press.
10. Relieve the pressure on the drill just before it breaks through a piece of metal to prevent binding, which may cause the piece of metal to spin or the drill to break.
11. Do not hold small work by hand when drilling on the drill press. Be sure you have at least 12 inches of leverage (distance from the hole being drilled to your hand) when holding work to be drilled. Clamp smaller pieces to the table or use a drill press vise to hold them securely while drilling.
12. Remove chips and shavings with a brush, not your hand. Never wear gloves when operating a drill press--gloves may get caught on the bit or chuck.

PORTABLE DRILL SAFETY

1. Be sure that the portable electric drill is grounded through the third wire in the attachment cord. It is safer to use a double-insulated drill.
2. Have a firm grip on a portable electric drill when drilling holes in metal. Portable drills of 1/2-inch capacity and larger may throw the operator off balance and cause serious injury if the bit catches while drilling.
3. Keep the connecting cord for the portable drill clear of the bit and chuck to prevent wrapping while operating the drill.
4. Never lock the switch in the "ON" position when a portable drill is held in your hands. The switch lock should be used only when the portable drill is fastened in a stand.

PNEUMATIC TOOL SAFETY

1. Pneumatic tool hoses must be secured to prevent accidental disconnection.
2. Compressed air can be used for cleaning only if pressure is less than 30 pounds per square inch (PSI) and it is used with an effective chip guard.
3. Any pneumatic hose over 1/2-inch in diameter must have a safety valve at the source that reduces pressure if the hose fails.
4. Couplings between hoses must have a safety connection in case the couplings fail to hold.
5. Never use pneumatic hoses for hoisting anything.
6. Use a dryer and filter to prevent moisture and dirt from entering the tool.
7. Be sure hose and fittings are in good condition and securely fastened before opening the air-line valve.
8. Never exceed the manufacturer's recommended pressure for tools.
9. Wear proper personal protection when using pneumatic tools.
10. When work is completed, shut the air supply off and then run the tool to drain the line before disconnecting.

COMPRESSOR SAFETY: Even though compressors are actually powered by electric motors or gasoline engines, they will be covered here because of their direct use with pneumatic tools.

1. Air storage tanks on compressors must be approved by the American Society of Mechanical Engineers (A.S.M.E.) and have this approval permanently stamped into them.
2. Drain the water out of the storage tanks at least daily, to prevent rust through and weak points.
3. Compressed air storage tanks must be equipped with a working safety relief valve to prevent exploding.
4. Keep the relief valve and pressure gauge in good working condition.

References:

1. Related Training Modules for Stationary Engineer. Eugene, Oregon: Lane Community College, 1985.
2. Smith, J., Safety in the Shop. Urbana, Illinois: College of Agriculture, University of Illinois, 1986.

Power Tool Safety Self-Test

Select the answer which best completes the statement. Write the letter of that answer in the blank to the left of the statement.

1. _____ All electric tools must have:

   a. cover guards
   b. grounding wires
   c. guard covers
   d. receptacles

2. _____ Circular saws should be used to cut:

   a. in the forward motion only
   b. in the backward motion only
   c. in non-ferrous woods
   d. crooked cuts

3. _____ One of the requirements for using compressed air for cleaning is that:

   a. pressure is less than 15 pounds per square foot
   b. pressure is less than 30 pounds per square foot
   c. pressure is less than 15 pounds per square inch
   d. pressure is less than 30 pounds per square inch

4. _____ Regarding pneumatic tool use, hose couplings should be:

   a. fitted with a safety connection
   b. subjected to no more than 15 pounds per square inch
   c. made of 1/2-inch hose
   d. fitted by compressed air

5. _____ When using a power hacksaw:

   a. clamp the blade in a saw vise
   b. install the blade so the teeth will point in the direction of cutting
   c. make a notch with a file to start the blade on sharp edges
   d. all of the above

6. _____ If the operator exceeds the air pressure recommended by the manufacturer:

   a. a blowup could occur
   b. ignition could occur
   c. paint droplets will condense
   d. the nozzle could get plugged up

7. _____ With a metal-cutting band saw you should:

a. clean the blade brushes frequently
b. keep the blade guide close to the material
c. reduce the speed of the blade if the saw teeth wear off unusually fast
d. all of the above

8. _____ When using a stationary grinder:

a. adjust tool rests after starting the grinder
b. adjust the tool rest to more than 1/8-inch away from the face of the wheel
c. grind only on the face of the wheel
d. a defective wheel will usually break and fly to pieces during the first two minutes of operation

9. _____ Air storage tanks on compressors must be approved by:

a. American Society of Mechanical Engineers
b. American Society of Mining Engineers
c. American Society of Compressor Engineers
d. American Society of Pressure Engineers

Power Tool Safety Self-Test Answers

1. b.
2. a
3. d
4. a
5. d
6. a
7. d
8. c
9. a

Power Tool Safety Test

Select the answer which best completes the statement. Write the letter for that answer in the blank at the left of each statement.

1. _____ With which of the following tools would you likely find coolant being used?

   a. circular saw
   b. reciprocating saw
   c. pneumatic stapler
   d. power hacksaw

2. _____ Compressed air can be used for cleaning only if the pressure is less than:

   a. 30 pounds per square inch (PSI)
   b. 3 PSI
   c. 60 PSI
   d. 15 PSI

3. _____ When you're finished using a pneumatic tool, you should:

   a. disconnect the air line, then shut the air supply off
   b. shut the air supply off, then disconnect the line
   c. disconnect the air line, then allow it to drain
   d. allow the line to build up pressure until the next job

4. _____ Any pneumatic hose over 1/2" in diameter should have a safety valve that reduces pressure if the hose fails. The safety valve should be located at:

   a. the source
   b. the tip
   c. the coupling
   d. the dryer

5. _____ In operating a portable circular saw, the saw blade should clear the stock by:

   a. 2-3 inches
   b. 1/4 inch
   c. 1/8 inch or less
   d. no more then 1/2 inch

6. _____ A portable circular saw must have a fixed guard over the upper half of the blade and:

   a. a fixed guard over the bottom half of the blade
   b. a portable guard over the bottom half of the blade
   c. a working movable guard over the bottom half of the blade
   d. a flexible guard over the bottom half of the blade

7. _____ Starting the saw and allowing it to come to full speed before cutting will prevent:

   a. overloading
   b. buckling
   c. burrs
   d. blade tension

8. _____ Couplings between hoses must have:

   a. safety valves
   b. safety harnesses
   c. safety connections
   d. safety tensions

True or False

9. _____ When using a power hacksaw, install the blade so the teeth will point opposite the direction of cutting.

10. _____ When using a drill press, relieve the pressure on the drill just before it breaks through a piece of metal to prevent binding.

Power Tool Safety Test Answers

1. d
2. d
3. b
4. a
5. c
6. c
7. a
8. c
9. F
10. T

Competency:
1. Demonstrate the use of the methods of measurement used in the trade.

Instructional Objectives:
1. Identify measuring instruments.
2. Read the sixteenth's rule.
3. Complete statements concerning rules for the use of calipers.
4. Read a micrometer.
5. Measure lines to the nearest quarter, eighth, and sixteenth of an inch.
6. Read a rule.
7. Measure inside and outside diameters.
8. Use the inside and outside calipers.
9. Read the micrometer settings.

Learning Activities:
1. Discuss in class sessions the Information Sheet from Section C - Unit III "Measuring" from Air Conditioning and Refrigeration Fundamentals.
2. Complete Assignment Sheet 1, "Measure Lines to the Nearest Quarter, Eighth and Sixteenth of an Inch," Assignment Sheet 2, "Read a Rule," Assignment Sheet 3, "Measure Inside and Outside Diameters," Assignment Sheet 5, "Use the Inside and Outside Calipers," and Assignment Sheet 6, "Read the Micrometer Settings."

Evaluation/Checkout:
1. Submit Assignment Sheets 1, 2, 3, 5, and 6.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:
1. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (800401), a student manual (800402), and a transparency set (800403) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets and tests.

Resources:

1. Audio-Visual Materials"
    - A. "Measurement Tools 1 and 2" videotapes are available from NUS Training Corporation.
    - B. "Outside Micrometer" and "Vernier Caliper" videotapes are available from Marshall Maintenance Productions.
    - C. "Measuring Instruments" videotape is available from Industrial Training Corporation.

Competency:

1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a joint.
3. Demonstrate the ability to silver braze joints and silver braze a copper to a steel joint.

Instructional Objectives:

1. Match terms related to soldering and welding equipment with their definitions.
2. Identify safety rules for using soldering and welding equipment.
3. Complete a list of statements concerning lighting, adjusting, and extinguishing the air-acetylene torch.
4. Arrange in order the steps for setting up the oxyacetylene torch.
5. Arrange in order the steps for lighting, adjusting, and extinguishing the oxyacetylene torch.
6. Demonstrate the ability to light and adjust the air-acetylene torch.
7. Match terms related to soft soldering with their definitions.
8. Arrange in order the steps in making a solder joint.
9. Distinguish between types of flux for soft solder.
10. List four conditions for creating capillary actions of solders.
11. Demonstrate the ability to clean, flux, and solder a joint with the air-acetylene torch.
12. Demonstrate the ability to clean, flux, and solder a joint with the oxyacetylene torch.
13. Match terms related to silver brazing with their definitions.
14. Match types of silver brazing alloys with their alloys and characteristics.
15. Select true statements concerning guidelines for using silver solder flux.
16. Match different temperature ranges with their correct flux characteristics.
17. Arrange in order the steps in using the air-acetylene high temperature wraparound tip for silver brazing.
18. Demonstrate the ability to silver braze a tube and fitting with a oxyacetylene torch.
19. Demonstrate the ability to silver braze a copper to a steel joint.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section E - Units I, II, and III, "Soldering and Welding Equipment," "Soft Soldering," and "Silver Brazing" from Air Conditioning and Refrigeration Fundamentals.
2. View the videotape "Brazing and Braze Welding" (Industrial Training Corporation).
3. Observe as your instructor demonstrates the proper use of soldering and welding equipment and demonstrates soft soldering and silver brazing.

Application Exercises:
1. Light and adjust the air-acetylene torch.
2. Clean, flux, and solder a joint with the air-acetylene torch.
3. Soft solder with the oxyacetylene torch.
4. Silver braze a tube and fitting with an oxyacetylene torch.
5. Silver braze a copper to a steel joint.

Evaluation/Checkout:
1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Soldering and welding equipment and equipment necessary to demonstrate soft soldering and silver brazing.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium 1984. An instructor's guide (800401), a student manual (800402), and a transparency set are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, selected activities, an information sheet , assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets and tests.

Audio-Visual Material:
1. The videotape "Brazing and Braze Welding" is available from Industrial Training Corporation. The following topics are covered: capillary action, brazing filler metals and fluxes, equipment setup, brazing aluminum, braze welding cast iron, soldering copper pipe, and brazing copper and carbon steel. The tape includes a workbook and facilitator's guide.

Resources:
1. Books
    - A. Lieberman, E., Modern Soldering and Brazing Techniques. Troy, Michigan: Business News Publishing, 1987.
    - B. Sosnin, H., Theory and Techniques of Soldering and Brazing of Pipe Systems. Elkhart, Indiana: NIBCO, Inc., 1971.
    - C. Steelworker 3 & 2 (Naval Education and Training Command Rate Training Manual - NAVEDTRA 10653-F1). Washington, D.C.: United States Government Printing Office, 1977. (Stock Ordering No. 0502-LP-053-2665)

D. Hull Maintenance Technician 3 & 2, Vol. 1 (Naval Education and Training Command Rate Training Manual - NAVEDTRA 10571). Washington, D.C.: United States Government Printing Office, 1984. (Stock Ordering No. 0502-LP-052-8630)

2. Audio-Visual Material:
   A. "Silver Brazing and Soft Soldering" is a videotape which is part of the Welding - Oxyacetylene Welding Series and is available from ICS - Intext, 315 Post Road West, Westport, CT 06880, (203)227-0891.
   B. "Soldering and Brazing Copper Tubing" is a videotape available from Marshall Maintenance Productions.
   C. "Soldering and Brazing Copper Tube" is a videotape available from NAPHCC, 180 S. Washington St., P.O. Box 6808, Falls Church, VA 22046, (800)533-7694.
   D. "Soldering: Tools and Techniques" is a videotape available from Industrial Training, Inc.
   E. "Silver Brazing and Soft Soldering" is a videotape which is part of the Welding Series Part I and is available from Video Training Resource, Inc.
   F. "Big League Soldering" is a videotape available from Hercules Chemical Company, Inc. Contact: Norman Stohl, Ad and Sales Promotion Manager, Hercules Chemical Company, Inc., 29 W. 38th Street, New York, NY 10018, (212)869-4330.
   G. "Practical Braze Training" is a videotape available from J.W. Harris Co., Inc. Contact: Glenna Parkins, J.W. Harris Co., Inc., 10930 Deerfield Road, Cincinnati, OH 45242, (513)891-2000.

Competency:

1. Demonstrate general safe practices for handling chemicals.
2. Demonstrate the ability to withdraw chlorine and/or caustic soda from containers.

Instructional Objectives:

1. Outline the emergency measures and procedures to be used in working with chlorine.
2. Identify first aid procedures to be used in case of chlorine exposure.
3. List the way chlorine shipments are received and handled.
4. Outline the proper procedure for withdrawing chlorine from containers.
5. Identify components of piping systems for chlorine.
6. Identify first aid procedures to be used in case of caustic soda exposure.
7. Outline the emergency measures and procedures to be used in working with caustic soda.
8. Outline the proper procedure for withdrawing caustic soda from containers.
9. Use the proper procedure to withdraw chlorine and/or caustic soda from containers.

Learning Activities:

1. Read Chapters 2, 4, 5, 6, and 7 in Chlorine from PPG Industries, Inc.
2. Read Chapters 3, 4, 5, and 6 in Caustic Soda from PPG Industries, Inc.
3. View the videotape "Chlorine Safety" (NUS Training Corporation) and the film "Be Careful With Caustic" (PPG Industries, Inc.).
4. Complete the Chemical Handling Worksheet.

Application Exercises:

1. Use the proper procedure to withdraw chlorine and/or caustic soda from containers.

Evaluation/Checkout:

1. Submit Chemical Handling Worksheet.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on-the-job. A list of the application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure. In this unit the apprentice can demonstrate the procedure for withdrawing chlorine, caustic soda, or both from containers depending on the needs of the apprentice's plant.

Learning Materials:

1. Chlorine. Pittsburgh, Pennsylvania: PPG Industries, Inc. 1986. This book is available from PPG Industries, Inc., Business Communications - Chemicals, One PPG Place, Pittsburgh, PA 15272.
2. Caustic Soda. Pittsburgh, Pennsylvania: PPG Industries, Inc., 1986. This book is available from PPG Industries, Inc. at the address listed above.
3. A copy of the worksheet and answers and test and answers is included with this unit.

Audio-Visual Materials:

1. The videotape "Chlorine Safety" is available from NUS Training Corporation. This tape is part of their Safety Partner Training Program.
2. The film "Be Careful With Caustic" is available from PPG Industries, Inc. at the address listed above.

Resources:

1. Books:
   - A. Chlorine Safe Handling. Pittsburgh, Pennsylvania: PPG Industries, Inc., 1986.
   - B. The Chlorine Institute publishes a number of relevant books and pamphlets including a Chlorine Manual and Chlorine Pipeline. A list of publications can be obtained from the Chlorine Institute, 2001 L. Street, N.W., Washington, D.C. 20036.
   - C. The Dow Chemical Company provides Material Data Safety Sheets for their products. Examples of the Sheets for Caustic Soda Beads, Caustic Soda, and Chlorine Liquid are included with this unit. These Sheets can be obtained from the Dow Chemical Company, Customer Information Center, 690 Building, Midland, MI 48667, (800) 258-CHEM.

2. Audio-Visual Materials:
   - A. "How to Use the Chlorine Institute Emergency Kit "A" for 100 and 150-lb. Chlorine Cylinders" is a slide/cassette available from the Chlorine Institute, 2001 L Street, N.W., Washington, D.C. 20036.
   - B. "How to Use the Chlorine Institute Emergency Kit "B" for Chlorine Ton Containers" is a slide/cassette available from the Chlorine Institute.
   - C. "How to Use the Chlorine Institute Emergency Kit "C" for Chlorine Tank Cars and Tank Trucks" is a slide/cassette or a film available from the Chlorine Institute.
   - D. "Safety First with Chlorine" is a film or tape available from PPG Industries, Inc.
   - E. "The Safe Handling of Pels Beads" is a slide/cassette available from PPG Industries, Inc.
   - G. "Introduction to Chemical Safety" is a videotape available from NUS Training Corporation.

H. "Chemical Safety," "Safe Chemical Handling, Part I," and "Safe Chemical Handling, Part II" are videotapes available from Industrial Training, Inc.
I. "Chemical Safety I: Proper Handling," "Chemical Safety II: Health Hazards," and "Chemical Safety III: Fire and Explosion" are videotapes available from Tel-A-Train, Inc.
J. "Chemical Hazards Training" is a series of seven videotapes available from Video Training Resource, Inc.

Chemical Handling Worksheet

1. List the emergency equipment that should be available when working with chlorine.

2. Where do most pipeline leaks occur?

3. Explain the procedure for dealing with a chlorine leak from a tank car or tank truck.

4. List health hazards associated with liquid chlorine.

5. What first aid procedures should be used in case of chlorine exposure?

6. What handling precautions should be taken when working with chlorine?

7. Outline the proper procedure for unloading chlorine from tank cars.

8. Outline the proper procedure for unloading chlorine from ton containers.

9. Why is it important for pipelines carrying chlorine to be protected against extremes of temperature?

10. List the essential parts of a piping system designed to unload a chlorine tank car, describe the purpose of each part, and specify a particular part type (for example, a diaphragm - type protected Bourdon tube gauge is recommended).

11. Explain the purpose of an expansion chamber on a pipeline carrying chlorine.

12. Ferric chloride is an indirect product of moisture in chlorine lines. Why should it be removed and how should it be removed?

13. List health hazards associated with caustic soda.

14. What first aid procedures should be used in case of caustic soda exposure?

15. What handling precautions should be taken when working with caustic soda?

16. List materials that are attacked by caustic soda and therefore should not be used in handling and storing caustic soda.

17. Why is it sometimes necessary to preheat caustic soda liquor before unloading a tank car?

18. State the procedure for thawing a frozen bottom discharge cock and internal valve at the bottom of a tank car containing caustic soda liquor.

19. Outline two methods that are used to unload caustic soda liquor from a tank car.

Chemical Handling Worksheet Answers

1. Respirators, chemicals and solution tanks, ammonia water, and capping kits.

2. At connections.

3. Leakage around the gasket of an angle valve or a safety valve can often be stopped by tightening the stud nuts on the valve or safety valve base flange. Leakage around the stem of an angle valve may usually be stopped by tightening the packing gland nuts. If these measures are not effective, use the emergency capping kit.

4. EYES: May cause severe irritation with corneal injury which may result in permanent impairment of vision, even blindness.
   SKIN CONTACT: Short single exposure may cause severe skin burns.
   INHALATION: A single brief (minutes) inhalation exposure to easily attainable concentrations may cause serious adverse effects, even death. Excessive exposure may cause severe irritation to upper respiratory tract and lungs and may cause lung injury.
   SYSTEMIC & OTHER EFFECTS: Excessive exposure may cause liver, lung and kidney effects, severe irritation to upper respiratory tract and lungs, and lung injury. Excessive exposure to chlorine gas has been known to also cause erosion of tooth enamel.

5. EYES: Immediate and continuous irrigation with flowing water for at least 30 minutes is imperative. Prompt medical consultation is essential
   SKIN: Wash off in flowing water or shower. Remove contaminated clothing immediately and launder before reuse.
   INHALATION: Remove to fresh air. If not breathing, give mouth-to-mouth resuscitation. If breathing is difficult, give oxygen. Call a physician.

6. VENTILATION: Use only with adequate ventilation. Local exhaust ventilation may be necessary for some operations. Lethal concentrations may exist in areas with poor ventilation.
   RESPIRATORY PROTECTION: When respiratory protection is required for certain operations, use an approved air-purifying respirator.
   SKIN PROTECTION: Use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, or full-body suit will depend on operation. Safety shower should be located in immediate work area. Remove contaminated clothing immediately and launder before reuse.
   EYE PROTECTION: Use chemical goggles. If vapor exposure causes eye irritation, use a positive pressure full-face respirator. Eye wash fountain should be located in immediate work area.

7. Answer is on page 24 in Chlorine.

8. Answer is on page 28 in Chlorine.

9. Liquid chlorine tends to vaporize as temperatures increase; gaseous chlorine tends to condense as temperatures decrease. Since this is not desirable, areas of either extreme should be avoided.

10. Answer is on pages 33, 37-40 in Chlorine.

11. Each pipeline or line section should be equipped with an expansion chamber to avoid trapped liquid chlorine from expanding and possibly creating enough pressure to burst the pipe.

12. Answer is on page 43 in Chlorine.

13. EYES: May cause severe irritation with corneal injury and result in permanent impairment of vision, even blindness. Dusts may irritate eyes.
SKIN CONTACT: Short single exposure may cause severe skin burns.
SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in absorption of harmful amounts.
INGESTION: May cause gastrointestinal irritation or ulceration and severe burns of the mouth and throat.
INHALATION: Dusts or mists may cause severe irritation to upper respiratory tract.

14. EYES: WATER is the only accepted method of removal of caustic soda (lye) from the eyes or skin. You may have 10 seconds or less to avoid serious permanent injury. Therefore, IMMEDIATE first aid must be given after any injurious exposure. Moving the victim from water access for transport to medical aid should be done only on the advice of qualified medical personnel. While transporting victim to a medical facility, continue washing if possible. In case of eye contact, wash eyes immediately and continuously for 30 minutes. Call for medical assistance immediately.
SKIN: Immediate continued and thorough washing in flowing water for 30 minutes is imperative while removing contaminated clothing. Prompt medical consultation is essential. Wash contaminated clothing before reuse. Destroy contaminated shoes.
INGESTION: Do not induce vomiting. Give large amounts of water or milk if available and transport to medical facility.
INHALATION: Remove to fresh air if effects occur. Consult medical.

15. VENTILATION: Control airborne concentrations below the exposure guideline. Good general ventilation sufficient for most operations.
RESPIRATORY PROTECTION: In misty atmospheres, use an approved mist respirator. If respiratory irritation is experienced, use an approved air-purifying respirator.
SKIN PROTECTION: Use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, hard hat with face-shield or full-body suit will depend on operation. Remove contaminated clothing immediately, wash skin area with soap and water, and launder clothing before reuse.
EYE PROTECTION: Use chemical goggles. Full face shield in addition to goggles may be desirable to protect face. Maintain eye wash fountain and safety shower at or near work area.

16. Aluminum, magnesium, zinc, tin, chromium, brass, bronzes made with zinc or tin, silica-containing materials, and copper.

17. Difficulty may be encountered in attempting to unload at lower temperatures (under 80 degrees F. for 50% caustic soda solution and under 185 degrees F. for 73% solution) since viscosity is then greater and there is a hazard of freezing in the unloading lines.

18. Answer is on page 24 in Caustic Soda.

19. Answer is on pages 26-28 in Caustic Soda.

Chemical Handling Test

1. State the first aid procedure to be used when caustic soda exposure occurs.

   Eyes:

   Skin:

   Ingestion:

   Inhalation:

2. Identify the effects chlorine exposure has on:

   Eyes:

   Skin:

   Inhalation:

3. _____ Leakage around the stem of an angle valve on a chlorine tank car or truck may usually be stopped by:

   a. tightening the flange bolts
   b. tapping the valve with a hammer
   c. tightening the packing gland nuts
   d. opening and closing the valve

4. _____ The first step in dealing with a chlorine leak in a ton container is:

   a. rotate the container so that the leak is in the uppermost portion
   b. rotate the container so that the leak is in the lowermost portion
   c. do not move the container
   d. cover the leak

5. _____ To neutralize spilled liquid chlorine you should use:

   a. water
   b. acetic acid
   c. boric acid
   d. granular soda ash

6. _____ The procedure for unloading chlorine from tank cars involves:

   a. making sure that shut-off valves in chlorine pipeline are closed
   b. setting brakes and chock tank car wheels
   c. checking leaks at all connections that were made using ammonia vapor
   d. all of the above

7. _____ True or False - You may use the discharge valve on a tank car to regulate chlorine flow.

8. _____ True or False - When unloading a tank car, the value in the vent line remains open until unloading is finished.

9. _____ True or False - Slow opening of the valves is emphasized when unloading a tank car.

10. _____ True or False - For tank cars having safety valves designed for 225 psi relief pressure, the air padding pressure should not exceed 125 psi.

11. _____ A chlorine tank car is empty when:

   a. only the pressure gauge on the gas line drops
   b. only the gauge on the liquid chlorine line drops
   c. the pressure gauge on the gas line and the gauge on the liquid chlorine line will equalize and drop together
   d. none of the above

12. Number in the proper order the procedure for withdrawing chlorine from ton containers.

_____ Install flexible connection between adaptor and permanent piping system.

_____ Remove valve protection hood from container and remove cap which covers valve outlet.

_____ Turn container discharge valve slowly, counterclockwise.

_____ Make sure valves in pipeline are closed.

_____ Make sure that the container is firmly blocked or otherwise held so that it will not roll.

_____ Attach adaptor to outlet valve, using the yoke to hold it firmly in place.

13. Match the following statements about piping systems for chlorine with their correct answer.

_____ In case of a break or leak this makes it possible to isolate the damaged section.

_____ This helps relieve the pressure within the pipeline if liquid chlorine becomes trapped in the line.

_____ This is used to relieve gas pressure in the line when unloading has been completed.

_____ This is designed to stop backflow from the line in case of a break between the shut-off valve and the container.

_____ Chemical reactions in the container between sucked backed liquids and chlorine can be prevented by use of this device.

a. vent line

b. check valve

c. shut-off valve

d. barometric leg

e. expansion chamber

14. _____ True or False - For chlorine pipelines, Schedule 80 seamless carbon steel pipe is recommended.

15. _____ True or False - PTFE tape or paste can be applied to the male threads of liquid and gas chlorine valve piping.

16. _____ Before any welding is done:

a. all piping and equipment must be purged of chlorine
b. all piping and equipment must be purged with dry air
c. check the leak area with an explosion meter
d. all of the above

17. _____ The usual material of construction for equipment handling 50 percent solutions of caustic soda below 140 degrees F is:

a. aluminum
b. galvanized iron
c. steel
d. chromium

18. _____ True or False - For transferring caustic liquor from tank car to storage, rotary pumps are recommended.

19. _____ True or False - In extremely cold weather, steam should be applied through the use of heating channels during the actual unloading of caustic soda liquor from tank cars.

20. _____ True or False - The 50% caustic soda solution is entirely fluid and can easily be unloaded when its temperature is above 80 degrees F.

21. _____ The recommended procedure for freeing a frozen internal valve in a tank car is:

a. to allow the tank car to warm up naturally
b. to apply steam to the tank contents
c. to apply hot water to the valve
d. to apply steam directly onto the internal valve

22. Number in the proper order the procedure for unloading caustic soda liquor from a tank car through the bottom outlet valve with a pump.

_____ Open the internal valve.

_____ Make sure the bottom cock is closed, then, while cupping palm of rubber gloved hand over the bottom cock to prevent caustic soda from spraying on you, remove the plug.

_____ Check the inside valve handle on top of the car and make sure it is closed.

_____ Open the bottom cock.

_____ Connect the unloading to the 2 inch bottom cock.

_____ Start pump.

_____ Open the manway cover and support it in a partially open position during unloading.

_____ Prepare empty car for return.

_____ After the flow starts, check piping valves and hose for leaks.

_____ See that all the valves on the unloading line are in the proper position for unloading.

_____ Carefully open the one-inch cock on the air connection on the top of the car to release any pressure or vacuum that might be in the car. Make sure to cup palm of rubber gloved hand over the top of one-inch cock.

_____ When the car is empty, stop the pump and close the internal valve.

Chemical Handling Test Answers

1. Eyes: Wash eyes immediately and continuously for 30 minutes.
   Skin: Immediate continued and thorough washing in flowing water for 30 minutes while contaminated clothing is removed. Prompt medical consultation is essential.
   Ingestion: Do not induce vomiting. Give large amounts of water or milk and transport to medical facility.
   Inhalation: Remove to fresh air.

2. Eyes: May cause severe irritation with corneal injury which may result in permanent impairment of vision.
   Skin: Severe skin burns may result.
   Inhalation: Brief inhalation may cause serious adverse effects while excessive exposure may cause severe irritation to upper respiratory tract and lungs.

3. c
4. a
5. d
6. d
7. False
8. False
9. True
10. True
11. c
12. 5
    3
    6
    2
    1
    4
13. c
    e
    a
    b
    d
14. True
15. True
16. d
17. c
18. False
19. False
20. True
21. d

22. 8
4
1
7
5
9
3
12
10
6
2
11

MATERIAL SAFETY DATA SHEET

DOW CHEMICAL U.S.A. MIDLAND, MICHIGAN 48674 EMERGENCY (517) • 636 • 4400

PRODUCT NAME: CAUSTIC SODA BEADS

Effective Date: 03/20/88 Date Printed: 10/28/88 MSDS:000100

1. INGREDIENTS: (% w/w, unless otherwise noted)

Sodium hydroxide (NaOH)	CAS# 001310-73-2	>98.5%
Sodium carbonate (Na2CO3)	CAS# 000497-19-8	< 0.65%
Sodium chloride (NaCl)	CAS# 007647-14-5	< 0.6%
Sodium sulfate (Na2SO4)	CAS# 007757-82-6	< 0.12%

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). In addition, other substances not 'Hazardous' per this OSHA Standard may be listed. Where proprietary ingredient shows, the identity may be made available as provided in this standard.

2. PHYSICAL DATA:

BOILING POINT: 1390C
VAP PRESS: Not applicable
VAP DENSITY: Not applicable
SOL. IN WATER: 109 gm/100 gm @ 20C
SP. GRAVITY: 70 lbs/cu ft
MELTING POINT: 604F, 318C.
APPEARANCE: White solid.
ODOR: No odor.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: Not applicable
METHOD USED: Not applicable

FLAMMABLE LIMITS
LFL: Not applicable
UFL: Not applicable

EXTINGUISHING MEDIA: Non-combustible.

(Continued on Page 2)

3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

FIRE & EXPLOSION HAZARDS: In water solution caustic can react with amphoteric metals (such as aluminum) generating hydrogen which is flammable and/or explosive if ignited.

FIRE-FIGHTING EQUIPMENT: Not available.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Product absorbs water and carbon dioxide from the air. Keep containers closed and sealed.

INCOMPATIBILITY: Water and acid. Product is strong caustic alkali. May react violently with water, acid, and a number of organic compounds. Caustic reacts rapidly with aluminum, tin, and zinc. It will also react with bronze and brass.

HAZARDOUS DECOMPOSITION PRODUCTS: None.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Only trained and properly protected personnel should be involved in spill cleanup operations. Acting cautiously, accidental spills of caustic soda beads must first be shoveled up. Then carefully, flush the spill area with water. Dilute acid, preferably acetic acid, may be used to neutralize only the final traces of caustic after flushing.

DISPOSAL METHOD: Disposal of caustic soda must meet all federal, state, and local regulations. Contact The Dow Chemical Company for additional information.

(Continued on Page 3)

6. HEALTH HAZARD DATA:

EYE: May cause severe irritation with corneal injury and result in permanent impairment of vision, even blindness. Dusts may irritate eyes.

SKIN CONTACT: Short single exposure may cause severe skin burns.

SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in absorption of harmful amounts. The dermal LD50 has not been determined.

INGESTION: May cause gastrointestinal irritation or ulceration, and severe burns of the mouth and throat. Single dose oral LD50 has not been determined.

INHALATION: Dusts or mists may cause severe irritation to upper respiratory tract.

SYSTEMIC & OTHER EFFECTS: No systemic effects are expected.

7. FIRST AID:

EYES: Wash eyes immediately and continuously until assistance arrives for transport to medical facility; wash enroute, if possible. If medical assistance is not immediately available, wash for 30 minutes and seek medical attention immediately.

SKIN: Immediate continued and thorough washing in flowing water for 30 minutes is imperative while removing contaminated clothing. Prompt medical consultation is essential. Wash contaminated clothing before reuse. Destroy contaminated shoes.

INGESTION: Do not induce vomiting. Give large amounts of water or milk if available and transport to medical facility.

(Continued on Page 4)

7. FIRST AID: (CONTINUED)

INHALATION: Remove to fresh air if effects occur. Consult medical.

NOTE TO PHYSICIAN: Corrosive. May cause stricture. If lavage is performed, suggest endotracheal and/or esophagoscopic control. Material is strong alkali. If burn is present, treat as any thermal burn, after decontamination. Eye irrigation may be necessary for an extended period of time to remove as much caustic as possible. Duration of irrigation and treatment is at the discretion of medical personnel. No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): Sodium hydroxide: ACGIH TLV is 2 mg/m3 ceiling; OSHA PEL is 2 mg/m3 (TWA).

VENTILATION: Control airborne concentrations below the exposure guideline. Local exhaust ventilation may be necessary for some operations.

RESPIRATORY PROTECTION: When airborne exposure guidelines and/or comfort levels may be exceeded, use an approved air-purifying respirator.

SKIN PROTECTION: Use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, hard hat with face-shield or full-body suit will depend on operation. Safety shower should be located in immediate work area. Remove contaminated clothing immediately, wash skin area with soap and water, and launder clothing before reuse. Contaminated leather items, such as shoes, belts, and watchbands, should be removed and destroyed.

(Continued on Page 5)

8. HANDLING PRECAUTIONS: (CONTINUED)

EYE PROTECTION: Use chemical goggles. Wear a face-shield which allows use of chemical goggles, or wear a full-face respirator, to protect face and eyes when there is any likelihood of splashes. Eye wash fountain should be located in immediate work area.

9. ADDITIONAL INFORMATION:

REGULATORY REQUIREMENTS:

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Prevent eye and skin contact. Do not breathe dusts or mists.

Avoid storing next to strong acids. Caustic should be stored in clean, dry areas. Do not store in underground tanks. Product absorbs water and CO2 from air. Keep containers closed and sealed.

Special precautions for dissolving beads:

1. Always add beads to the liquid. Never add the liquid to the beads.
2. The liquid should be lukewarm (80-100F). Never start with hot or cold liquid.
3. Always sprinkle the beads slowly over the surface of the

(Continued on Page 6)

9. ADDITIONAL INFORMATION: (CONTINUED)

constantly stirred liquid.
The addition of caustic soda to liquid will cause a rise in temperature. If caustic soda becomes concentrated in one area, or is added too rapidly, or is added to hot or cold liquid, a rapid temperature increase can result in dangerous mists or boiling or spattering which may cause an immediate violent eruption.

MSDS STATUS: Revised Section 9.

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The Information Herein Is Given In Good Faith, But No Warranty, Express Or Implied, Is Made. Consult The Dow Chemical Company For Further Information.

MATERIAL SAFETY DATA SHEET

DOW CHEMICAL U.S.A. MIDLAND, MICHIGAN 48674 EMERGENCY (517) • 636 • 4400

Product Code: 15303 Page: 1

PRODUCT NAME: CAUSTIC SODA - E, 50% SOLUTION

Effective Date: 03/20/88 Date Printed: 10/28/88 MSDS:000101

1. INGREDIENTS: (% w/w, unless otherwise noted)

Sodium hydroxide (NaOH)	CAS# 001310-73-2	48.5-50.5%
Sodium carbonate (Na2CO3)	CAS# 000497-19-8	<0.2%
Sodium chloride (NaCl)	CAS# 007647-14-5	<1.0%
Water	CAS# 007732-18-5	BAL

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). In addition, other substances not 'Hazardous' per this OSHA Standard may be listed. Where proprietary ingredient shows, the identity may be made available as provided in this standard.

2. PHYSICAL DATA:

BOILING POINT: 293F, 145C approx.
VAP. PRESS: 1.5 mmHg, 0.2 kPa @ 20C
VAP. DENSITY: Not applicable
SOL. IN WATER: Water solution
SP. GRAVITY: @ 20C (Dens.) 1.52 g/ml
APPEARANCE: Colorless to slightly colored liquid.
ODOR: No odor.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: None
METHOD USED: Not applicable

FLAMMABLE LIMITS
LFL: Not applic.
UFL: Not applic.

EXTINGUISHING MEDIA: Non-combustible.

FIRE & EXPLOSION HAZARDS: In water solution caustic can react

(Continued on Page 2)

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3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

with amphoteric metals (such as aluminum) generating hydrogen which is flammable and/or explosive if ignited.

FIRE-FIGHTING EQUIPMENT: Wear positive pressure self-contained breathing apparatus.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Product absorbs water and carbon dioxide from the air. Keep containers closed and sealed.

INCOMPATIBILITY: Water and acid. Product is strong caustic alkali. May react violently with water, acid, and a number of organic compounds. Caustic reacts rapidly with aluminum, tin, and zinc. It will also react with bronze and brass.

HAZARDOUS DECOMPOSITION PRODUCTS: None.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Only trained and properly protected personnel should be involved in spill cleanup operations. Acting cautiously, small accidental spills of caustic soda solution should be carefully flushed with water. Dilute acid, preferably acetic acid, may be used to neutralize only the final traces of caustic after flushing.

DISPOSAL METHOD: Disposal of caustic soda must meet all federal, state, and local regulations. Contact The Dow Chemical Company for additional information.

(Continued on Page 3)

6. HEALTH HAZARD DATA:

EYE: May cause severe irritation with corneal injury and result in permanent impairment of vision, even blindness. Dusts may irritate eyes.

SKIN CONTACT: Short single exposure may cause severe skin burns.

SKIN ABSORPTION: A single prolonged skin exposure is not likely to result in absorption of harmful amounts. The dermal LD50 has not been determined.

INGESTION: May cause gastrointestinal irritation or ulceration and severe burns of the mouth and throat. Single dose oral LD50 has not been determined.

INHALATION: Dusts or mists may cause severe irritation to upper respiratory tract.

SYSTEMIC & OTHER EFFECTS: No relevant information found.

7. FIRST AID:

EYES: WATER is the only accepted method of removal of caustic soda (lye) from the eyes or skin. You may have 10 seconds or less to avoid serious permanent injury. Therefore, IMMEDIATE first aid must be given after any injurious exposure. Moving the victim from water access for transport to medical aid should be done only on the advice of qualified medical personnel. While transporting victim to a medical facility, continue washing if possible.

In case of eye contact, wash eyes immediately and continuously for 30 minutes. Call for medical assistance immediately.

SKIN: Immediate continued and thorough washing in flowing water

(Continued on Page 4)

7. FIRST AID: (CONTINUED)

for 30 minutes is imperative while removing contaminated clothing. Prompt medical consultation is essential. Wash contaminated clothing before reuse. Destroy contaminated shoes.

INGESTION: Do not induce vomiting. Give large amounts of water or milk if available and transport to medical facility.

INHALATION: Remove to fresh air if effects occur. Consult medical.

NOTE TO PHYSICIAN: Corrosive. May cause stricture. If lavage is performed, suggest endotracheal and/or esophagoscopic control. Material is strong alkali. If burn is present, treat as any thermal burn, after decontamination. For burns of skin only. Eye irrigation may be necessary for an extended period of time to remove as much caustic as possible. Duration of irrigation and treatment is at the discretion of medical personnel. No specific antidote. Supportive care. Treatment based on judgment of the physician in response to reactions of the patient.

8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): Sodium hydroxide: ACGIH TLV is 2 mg/m3 ceiling; OSHA PEL is 2 mg/m3 (TWA).

VENTILATION: Control airborne concentrations below the exposure guideline. Good general ventilation sufficient for most operations.

RESPIRATORY PROTECTION: In misty atmospheres, use an approved mist respirator. If respiratory irritation is experienced, use an approved air-purifying respirator.

(Continued on Page 5)

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8. HANDLING PRECAUTIONS: (CONTINUED)

SKIN PROTECTION: Use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, hard hat with face-shield or full-body suit will depend on operation. Remove contaminated clothing immediately, wash skin area with soap and water, and launder clothing before reuse.

EYE PROTECTION: Use chemical goggles. Full face shield in addition to goggles may be desirable to protect face. Maintain eye wash fountain and safety shower at or near work area.

9. ADDITIONAL INFORMATION:

REGULATORY REQUIREMENTS:

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: Prevent eye and skin contact. Do not breathe dusts or mists.

Avoid storing next to strong acids. Caustic should be stored in clean, dry areas. Do not store in underground tanks. Product absorbs water and CO2 from air. Keep containers closed and sealed.

SPECIAL PRECAUTIONS FOR DILUTING CAUSTIC SODA SOLUTION:
1. ALWAYS add caustic soda solution to water with constant

(Continued on Page 6)

9. ADDITIONAL INFORMATION: (CONTINUED)

agitation. NEVER add water to the caustic soda solution.
2. The water should be lukewarm (80-100F). NEVER start with hot or cold water.

The addition of caustic soda to liquid will cause a rise in temperature. If caustic soda becomes concentrated in one area, or is added too rapidly, or is added to hot or cold liquid, a rapid temperature increase can result in DANGEROUS mists or boiling or spattering which may cause an immediate VIOLENT ERUPTION.

MSDS STATUS: Revised Section 9.

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DOW

MATERIAL SAFETY DATA SHEET

DOW CHEMICAL U.S.A. MIDLAND, MICHIGAN 48674 EMERGENCY (517) • 636 • 4400

Product Code: 16295 Page: 1

PRODUCT NAME: CHLORINE, LIQUID

Effective Date: 04/20/88 Date Printed: 10/28/88 MSDS:001122

1. INGREDIENTS: (% w/w, unless otherwise noted)

Chlorine	CAS# 007782-50-5	99.9%

This document is prepared pursuant to the OSHA Hazard Communication Standard (29 CFR 1910.1200). In addition, other substances not 'Hazardous' per this OSHA Standard may be listed. Where proprietary ingredient shows, the identity may be made available as provided in this standard.

2. PHYSICAL DATA:

BOILING POINT: -29.3F (-34C)
VAP PRESS: 82 psig @ 68F, 20C
VAP DENSITY: 2.49 @ 32F,0C
SOL. IN WATER: 0.73g/100g H20 @ 20C
SP. GRAVITY: 1.47 @ 32F, 0C; 53.2 psia
APPEARANCE: Amber color; liquified gas under pressure; vaporizes to greenish - yellow gas.
ODOR: Pungent odor.

3. FIRE AND EXPLOSION HAZARD DATA:

FLASH POINT: None
METHOD USED: Not applicable

FLAMMABLE LIMITS
LFL: Not applicable
UFL: Not applicable

EXTINGUISHING MEDIA: Chlorine will react or cause reducing materials to burn without oxygen. Water is effective only as a cooling media to reduce the reaction rate, however, water should not be applied directly to the chlorine leak. Where practical attempts should be made to reduce the available

(Continued on Page 2)

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3. FIRE AND EXPLOSION HAZARD DATA: (CONTINUED)

reactants through the isolation of the reaction from the chemical supply. This should be attempted only by properly trained personnel using prescribed protective equipment.

FIRE & EXPLOSION HAZARDS: May react to cause fire and/or explosion upon contact with many organic compounds, ammonia, hydrogen, or many metals, and with all metals, including steel, at elevated temperatures.

FIRE-FIGHTING EQUIPMENT: A positive pressure self-contained breathing apparatus for respiratory protection and protective clothing.

4. REACTIVITY DATA:

STABILITY: (CONDITIONS TO AVOID) Avoid proximity to flammable materials including chemicals.

INCOMPATIBILITY: (SPECIFIC MATERIALS TO AVOID) Many organic compounds, ammonia, hydrogen, moist or hot steel, and many metals. May react explosively with some organics under confinement.

HAZARDOUS DECOMPOSITION PRODUCTS: None.

HAZARDOUS POLYMERIZATION: Will not occur.

5. ENVIRONMENTAL AND DISPOSAL INFORMATION:

ACTION TO TAKE FOR SPILLS/LEAKS: Move unprotected personnel cross-wind to a clear area. Do not use water directly on a chlorine leak. A fog nozzle may be used to absorb gas. The leak should be isolated or controlled by trained personnel

(Continued on Page 3)

5. ENVIRONMENTAL AND DISPOSAL INFORMATION: (CONTINUED)

using prescribed protective equipment.

DISPOSAL METHOD: Prior to disposal, the active chlorine must be reduced or destroyed. Chlorine may be absorbed in dilute solutions of caustic (NaOH), soda ash (Na_2CO_3), or hydrated lime ($Ca(OH)_2$). Caustic and soda ash solutions should contain approximately 3 pounds per gallon, lime 1 pound per gallon, for 1 pound chlorine. Local, municipal or state authorities should be contacted for disposal of resultant product.

6. HEALTH HAZARD DATA:

EYE: May cause severe irritation with corneal injury which may result in permanent impairment of vision, even blindness.

SKIN CONTACT: Short single exposure may cause severe skin burns.

SKIN ABSORPTION: The dermal LD50 has not been determined.

INGESTION: Ingestion is unlikely due to physical state.

INHALATION: A single brief (minutes) inhalation exposure to easily attainable concentrations may cause serious adverse effects, even death. Excessive exposure may cause severe irritation to upper respiratory tract and lungs and may cause lung injury. The LC50 for mice was 137 ppm and for rats 293 ppm for 1 hour.

SYSTEMIC & OTHER EFFECTS: Excessive exposure may cause liver, lung and kidney effects, severe irritation to upper respiratory tract and lungs, and lung injury. Excessive exposure to chlorine gas has been known to also cause erosion of tooth enamel. No evidence has been found that chlorine is a carcinogen. Limited data suggests that chlorine is not

(Continued on Page 4)

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6. HEALTH HAZARD DATA: (CONTINUED)

teratogenic but may be slightly embryotoxic when administered at high doses in drinking water to pregnant rats. In animal studies, has been shown not to interfere with reproduction. Results of mutagenicity tests in animals have been negative. Has been shown to have mutagenic activity in bacteria.

7. FIRST AID:

EYES: Immediate and continuous irrigation with flowing water for at least 30 minutes is imperative. Prompt medical consultation is essential.

SKIN: Wash off in flowing water or shower. Remove contaminated clothing immediately and launder before reuse.

INGESTION: No adverse effects anticipated by this route of exposure due to gaseous state.

INHALATION: Remove to fresh air. If not breathing, give mouth-to-mouth resuscitation. If breathing is difficult, give oxygen. Call a physician.

NOTE TO PHYSICIAN: If burn is present, treat as any thermal burn, after decontamination. Excellent warning properties force rapid escape from chlorine gas; thus most inhalations are mild to moderate. If escape is not possible, exposure to high concentrations for a very short time can result in dyspnea, hemoptysis and cyanosis with later complications being tracheobronchopneumonitis and pulmonary edema. Oxygen, intermittent positive pressure breathing and aerosolized bronchodilators are of therapeutic value in the light to moderate inhalation. A severe inhalation should be hospitalized and treated as a respiratory emergency. Any chlorine inhalation in an individual with compromised pulmonary

(Continued on Page 5)

7. FIRST AID: (CONTINUED)

function (COPD) should be regarded as a severe inhalation and a respiratory emergency.

8. HANDLING PRECAUTIONS:

EXPOSURE GUIDELINE(S): ACGIH TLV is 1 ppm TWA; the STEL is 3 ppm. The OSHA PEL is 1 ppm ceiling.

VENTILATION: Control airborne concentrations below the exposure guideline. Use only with adequate ventilation. Local exhaust ventilation may be necessary for some operations. Lethal concentrations may exist in areas with poor ventilation.

RESPIRATORY PROTECTION: Atmospheric levels should be maintained below the exposure guideline. When respiratory protection is required for certain operations, use an approved air-purifying respirator.

SKIN PROTECTION: Use protective clothing impervious to this material. Selection of specific items such as gloves, boots, apron, or full-body suit will depend on operation. Safety shower should be located in immediate work area. Remove contaminated clothing immediately and launder before reuse.

EYE PROTECTION: Use chemical goggles. If vapor exposure causes eye irritation, use a positive pressure full-face respirator. Eye wash fountain should be located in immediate work area.

(Continued on Page 6)

9. ADDITIONAL INFORMATION:

REGULATORY REQUIREMENTS:

SARA HAZARD CATEGORY: This product has been reviewed according to the EPA 'Hazard Categories' promulgated under Sections 311 and 312 of the Superfund Amendment and Reauthorization Act of 1986 (SARA Title III) and is considered, under applicable definitions, to meet the following categories:

An immediate health hazard
A delayed health hazard
A sudden release of pressure hazard
A reactive hazard

SPECIAL PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: No attempt should be made to handle or store chlorine without a complete review of the chlorine manual, available from the Chlorine Institute, Inc., New York.

MSDS STATUS: Revised Section 1.

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Competency:

1. Describe various types of hot water heating systems.
2. Identify types of boilers and appropriate safety devices for hot water heating systems.
3. Explain venting and piping considerations for hot water heating systems.
4. Demonstrate the ability to maintain a hot water heating system.

Instructional Objectives:

1. Explain the operation of a one-pipe hot water heating system.
2. Explain the operation of a two-pipe direct return and a two-pipe reverse return hot water heating system.
3. Explain the operation of a series loop hot water heating system.
4. Explain why forced circulation hot water heating is preferred over gravity circulation.
5. Identify the various hot water heating fittings and accessories that are necessary for safe and efficient operation.
6. Describe the role of the expansion tank in a hot water heating system.
7. Explain the advantages and disadvantages of hot water heating over steam heating systems.
8. Explain how to remove all the air from hot water heating systems.
9. Draw and explain how to make proper piping connections for four types of hot water heating systems.
10. Troubleshoot a hot water heating system that is not operating properly.
11. Install a pressure reducing valve on a hot water heating system.
12. Install a stop valve on a hot water heating system.
13. Install a safety relief valve on a hot water heating system.

Learning Activities:

1. Read Chapter 7 and pp. 519-542 in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Hydronic Heating" - Lecture 10 and pp. 28-39 in "Boiler Fittings" - Lecture 3 in Building Systems Technician - Course 2.
2. Read "Basic Controls for Hot Water Boilers" (Bulletin SL-BCHW) from McDonnell and Miller, ITT Corporation.
3. Read Hot Water Heating Systems Troubleshooting Information Sheet.
4. Complete Assignment 1 - "Diagram a One-Pipe Hot Water Heating System."
5. Complete Assignment 2 - "Diagram a Two-Pipe Direct Return and Two-Pipe Reverse Return Hot Water Heating System."
6. Complete Assignment 3 - "Diagram a Series-Loop Hot Water Heating System."
7. Complete Assignment 4 - "Diagram a Hot Water Heating Boiler."

Application Exercises:

1. Troubleshoot a hot water heating system that is not operating properly.
2. Install a pressure reducing valve on a hot water heating system.
3. Install a stop valve on a hot water heating system.
4. Install a safety relief valve on a hot water heating system.

Evaluation/Checkout:

1. Submit Assignment Sheets 1, 2, 3, & 4.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Brumbaugh, J. Heating, Ventilating, and Air Conditioning Library - Volume I. New York: Macmillan Publishing Company, 1986.
2. Building Systems Technician - Course 2. Calgary, Alberta: Southern Alberta Institute of Technology, 1986.
3. "Basic Controls for Hot Water Boilers" (Bulletin SL-BCHW) is available from McDonnell and Miller, ITT Corporation, Attn: Marketing Services Department, 3500 N. Spaulding Avenue, Chicago, IL 60618, (312) 267-1600
4. A copy of the information sheet, assignment sheets, and test and answers is included with this unit.

Resources:

1. Books:
    - A. Steingress, F. Low Pressure Boilers - 2nd edition. Homewood, Illinois: American Technical Publishers, 1986.
    - B. Hansen, E. Hydronic System Design and Operation. New York: McGraw-Hill, 1985.
    - C. Hydronics. Troy, Michigan: Business News Publishing Company, 1981.

2. Pamphlets:
    - A. The Hydronics Institute, Inc. has numerous publications available. Contact Richard W. Roth, Director of Public Relations, The Hydronics Institute, Inc., 35 Russo Place, P. O. Box 218, Berkeley Heights, NJ 07922, (201) 464-8200.
    - B. "Flow Switch Application Guidebook" (Bulletin SL-FSGB) is available from McDonnell and Miller, ITT Corporation, Attn: Marketing Services Department, 3500 N. Spaulding Avenue, Chicago, Illinois, 60618, (312) 267-1600.

C. Burnham Corporation has sales literature and installation, operations and service instructions available for their boilers. Contact: Burnham Corporation, Hydronics Division, P. O. Box 3079, Lancaster, PA 17604-3079.

D. "Feed Water Pressure Regulators" (F-1156-5), "Pressure Relief Valves" (F-TP-ASME), "Floatvent FV4" (S-FV4), "Hot Water Extender Tempering Valves" (F-N170-M1-3) are available from Rich Davison, Jr., Watts Regulator Company, c/o Advance Industrial Marketing, P. O. Box 87, 923 S. Bird Street, Sun Prairie, WI 53590, (608) 837-5005.

E. "Analysis of Hydronic System Problems" (Bulletin No. TEH-966) is from Bell and Gossett available from ITT Fluid Handling Division, Training and Education Department, 4711 Golf Road, Skokie, IL 60076, (312) 677-4030.

F. Weil-McLain Hydronics Education and Training is a series of video-based training courses on hydronic systems. Contact: Weil-McLain, H.E.A.T. Department, Blaine Street, Michigan City, IN 46360, ask for Form No. H.E.A.T. 884(688) for a descriptive brochure.

3. Audio-Visual Materials:
   A. "Heat Exchangers" is a videotape available from Industrial Training Corporation.
   B. "Heat Exchangers 1 and 2" are videotapes available from NUS Training Corporation.

Assignment Sheet 1

Diagram a One-Pipe Hot Water Heating System

Draw a simple sketch of a one-pipe hot water heating system including the following components: boiler, air separator, expansion tank, circulating pump, air vent, diverter fittings, and convectors and show how the pipes are pitched and the direction of the flow of the water. Explain the advantages and disadvantages of the system and the purpose of each of the components.

Assignment Sheet 2

Diagram a Two-Pipe Direct Return and a Two-Pipe Reverse Return Hot Water Heating System

Draw a simple sketch of a two-pipe direct return and of a two-pipe reverse return hot water heating system including the following components: boiler, air separator, expansion tank, circulating pump, air vent, and convectors and show how the pipes are pitched and the direction of the flow of the water. Explain the advantages and disadvantages of each system and the purpose of each of the components.

Assignment Sheet 3

Diagram a Series Loop Hot Water Heating System

Draw a simple sketch of a series loop hot water heating system including the following components: boiler, flow control valves, circulating pump, expansion tank, air separator, air vents, and convectors and show the direction of the flow of the water. Explain the advantages and disadvantages of the system and the purpose of each of the components.

Assignment Sheet 4

Diagram a Hot Water Heating Boiler

Draw a simple sketch of a hot water heating boiler with the necessary fittings and controls including pressure gauge, thermometer, safety relief valve, stop valves on return and supply lines, blow-off on drain valve, pressure reducing valve, expansion tank, low water fuel cut-off, operating temperature control, and high limit temperature control. Explain the purpose of each of these.

Hot Water Heating Systems Troubleshooting Information Sheet

Summary

Quite often when the complaint is, we don't have any heat and the heat pump is running, the blame is put on the pump.

A circulating pump causes circulation to take place in a piping system by maintaining a pressure differential between its suction and discharge openings. The more pressure drop in a line, the less flow there will be with a given pump. If piping is added to a system, the pressure drop across the system would increase and water flow would decrease.

Motor load increases with the flow in a given pump.

1. When checking the circulating pump for proper operation, what are some of the things you are looking for?

   You are looking for a pressure differential between the suction and discharge side of the pump. You should also investigate the pump to make sure it is rotating in the right direction.

2. What is meant when we say the pump is operating at free delivery?

   When the pump creates no external pressure.

3. By increasing the pressure on a pump we will increase the flow. True or False.

   False. As pump pressure drop increases, pump flow or pump capacity decreases.

4. The direction of rotation for the impeller is important. How do we know if the impeller is going in the right direction?

   On the centrifugal pump the impeller should have the vanes slapping the water not digging in.

5. If a pump is very noisy, what could be the problem?

   The pump could be turning in the wrong direction.

Summary

One indication of insufficient circulation is a large temperature drop between the suction and discharge side of the system. Another cause could be air binding of the system.

Air must be vented from the heating system to insure proper circulation of the hot water.

A vent valve should be provided on all hot water boilers.

Install an isolating valve in the piping past the reducing valve but before the compression tank. This is required by the A.S.M.E. code.

1. The rotation of the impeller on a centrifugal pump is such that the vanes are always digging in the water? True or False.

   False. The vanes on the impeller should be slapping the water.

2. Air can cause circulation problems. True or False.

   True. Air if not vented will act as a break in the system water supply and will prevent circulation.

3. Where in the system would you install a vent valve and why?

   Vent valves should be installed on the high points of the system, since this is where the air will be.

4. An isolating valve would be installed where and what would be the purpose of the isolating valve?

   The purpose of this valve is to isolate the compression or expansion tank while simultaneously draining it. This isolating valve is required by A.S.M.E. code. Without this valve you would have to shut down the boiler and drain the system, not just the expansion or compression tank.

Summary

A column of water 27" high exerts a pressure of one P.S.I. at its base.

Static or system pressure has no effect on the pump circulation.
Subtract the suction pressure from the discharge pressure of the pump.
Take this number and multiply by 2.3' to get pressure drop in feet of head.

Over oiling can cause coupler alignment problems.

1. Twenty four inches of water column equals 1 P.S.I. True or False.

   False. 2.3 feet of water column equals 1 P.S.I.

2. Static head reduces flow output of the pump?

   Static head has no effect on pump performance as the same pressure exerted on both sides of the pump in a closed system.

3. By taking pressure readings on the pump, explain in detail how you could check pump performance.

   Take the pressure readings on the suction and the discharge sides of the pump. Use the differential between the two readings when referring to the pump performance curve for that pump. This will enable you to determine the flow in gallons per minute or output of the pump.

4. What would a pump performance curve show?

   Capacity of the pump as it related directly to pressure differential.

Summary

When a boiler comes up to temperature it drives off much of the air in solution. This air goes into the system piping.

Water logged expansion tanks or compression tanks can cause problems.

There must be a way of draining the expansion tank.

There must be an isolating valve on the piping going to the expansion tank.

1. Explain in detail how expansion tanks become water logged.

   When air is used to create head, expansion or compression tanks can become water logged. As the water is heated it drives air out through the vents and out of the system. When the water cools, it will reabsorb any air that is available. Since the only air remaining is in the expansion or compression tank, these tanks will become water logged.

2. Every time the burner operates the safety relief valve opens. What is happening?

   The expansion or compression tank is water logged or the isolating valve for the expansion tank is shut off.

3. Why must there be a drain on the expansion tank?

   To drain a water logged expansion.

4. What is the isolating valve and where is it located?

   The isolating valve is used to isolate the expansion/compression tank. This valve is located on the pipe going to the tank.

Summary

Proper pump lubrication is the single most important factor in pump longevity.

Over oiling damages motor mountings which in turn causes coupler breakage.

Frequent seal failures are generally due to a water condition which may be due to various additives being used in the system.

A mechanically sealed pump should never be run dry.

Automatic air vents are classified float or washer type.

1. The safety relief valve operates every time the burner comes on. Why?

   The expansion/compression tank is filled with water or the isolating valve is closed.

2. What is the single most important factor in pump longevity?

   Proper pump lubrication.

3. What could cause frequent mechanical seal failure?

   Over oiling.

4. Explain how an automatic float and washer type air vents work.

   An automatic float type air bleed has a lever operated vent with a float attached to it. When water is present the float will float, and the vent will be shut off. When air is present the float will not float, and therefore the vent will open allowing air to escape. Float types will handle large amounts of air.

5. Can mechanically sealed pumps be run dry?

   Mechanically sealed pumps should never be run dry, since the pump fluid carries away the frictional heat generated. If this heat is not dissipated the seal will fail.

Reference:

1. Berger, B. and Seidler, D. Stationery Steam Engineering Curriculum. White Bear Lake, Minnesota: Minnesota Curriculum Services Center, 1984.

Hot Water Heating Systems Test

1. When determining the rotation of a centrifugal pump used in a hydronic system,

   A. The impeller vanes should be slapping the water.
   B. The impeller vanes should be digging into the water.
   C. Makes no difference.

2. Assuming all components in a hydronic system are working, what would be the main reason for no heat?

   A. Water too cold.
   B. Not enough pressure.
   C. Air in the system.

3. If air is slowly leaking from an expansion tank on a hydronic system, where would you most likely find the leak?

   A. The rubber bushings on the gauge glass.
   B. On the safety valve leaving the expansion tank.
   C. Water would leak out before air.
   D. None of the above.

4. The following boilers are rated equally. A hydronic boiler uses a recirculating pump. A steam boiler uses a feed water pump. Which boiler must use the pump with the greater horsepower?

   A. The hydronic boiler needs a pump with more horsepower.
   B. The steam boiler will require a larger pump, more horsepower.
   C. Both are the same.
   D. None of the above.

5. On a hydronic system, what kind of valves are used to control and even out flow?

   A. Balancing valves normally installed on the return lines.
   B. Air cocks always located on the discharge side.
   C. Check valves.
   D. None of the above.

6. On a closed system, why must there be a drain line on the expansion or compression tank?

   A. So that any extra air can be evacuated from the system.
   B. If the expansion or compression tanks become water logged, there must be a way of draining them.
   C. A drain line is not required on a closed hot water system.
   D. A drain line is only required on an open hydronic system.

7. A hot water boiler is considered to be a low pressure boiler when it ____________________.

   A. Does not exceed 15 p.s.i.g.
   B. Exceeds 100 p.s.i.g.
   C. Does not exceed 250 degrees F. in temperature nor 160 pounds per square inch in pressure.
   D. Stays below 212 degrees F. in temperature and is 100 p.s.i.g. in pressure.

8. What is the purpose of an expansion tank used with a hot water boiler?

   A. The expansion tank will hold extra water for operation of the boiler.
   B. It has little value and could be plugged.
   C. The expansion tank allows for expansion and contraction of the water volume as its temperature varies.
   D. None of the answers given.

9. What firing control will help prevent thermal shock to a hot water boiler?

   A. An operating pressure control.
   B. A high limit control.
   C. A low limit temperature control.
   D. All of the answers mentioned are correct.

10. Can air cause circulation problems in a hot water system?

   A. No.
   B. Yes.
   C. Sometimes.
   D. Only if the water is cold.

11. On a hot water system where would you install an air bleeder?

   A. At the low point in the system.
   B. Anywhere in the system.
   C. At the high points in the system.
   D. Before each valve in the system.

12. What is the purpose of an isolating valve?

   A. To isolate the expansion tank (while the boiler is in operation) so that it can be drained.
   B. The isolating valve shuts off the hot water boiler.
   C. The isolating valve shuts off the boiler feed water pump.
   D. None of the answers given.

13. What would a pump performance curve chart show?

    A. The temperature on the suction and discharge side of the pump.
    B. The horsepower of the pump.
    C. The output of the pump in gallons per minute.
    D. All of the answers mentioned.

14. Will static head in a hot water system reduce the output of the recirculating pump in gallons per minute?

    A. It depends upon the temperature of the water.
    B. Yes.
    C. No.
    D. None of the answers given.

15. Name one way an expansion tank can become water logged.

    A. Air could escape past the upper gauge glass fitting.
    B. Too much pressure in the system.
    C. Not enough pressure in the system.
    D. None of the answers given.

16. A device that controls the starting and stopping of the burner on a hot water boiler is a/an ____________________.

    A. Pressuretrol.
    B. Aqua stat.
    C. Low water cut out.
    D. Sail switch

17. If the expansion or compression tank becomes water logged and the burner starts, what may happen?

    A. Nothing.
    B. Boiler will explode.
    C. Safety relief valve may lift.
    D. The pressure in the system will decrease.

18. When comparing a hot water boiler to a steam boiler, what auxiliaries are eliminated?

    A. Steam traps, condensate tanks and pumps.
    B. Both systems need the same auxiliaries.
    C. Strainers and recirculating pump.
    D. Aqua stats and recirculating pumps.

19. In addition to a safety relief valve, what other safety device should be installed on a hot water boiler?

    A. A safety purge valve.
    B. A low water fuel cut-out control.
    C. Pressuretrol.
    D. All of the answers given.

20. Can a hot water boiler have a low water condition?

A. Yes, for numerous reasons.
B. No, because the system is filled with water.
C. Not enough information for an answer.
D. None of the answers given.

21. Draw a simple sketch of a hot water boiler and clearly locate the following fittings and controls on it: (1) expansion tank with drain valve and gauge glass; (2) circulating pump; (3) blow-off or drain valve; (4) pressure gauge; (5) relief valve; (6) high limit temperature control; (7) stop valves on return and supply lines; (8) operating temperature control; (9) automatic low water fuel cut-off; (10) thermometer; (11) pressure reducing valve; and (12) an air separator.

22. Why is forced circulation hot water heating preferred over gravity circulation?

23. Describe three advantages and three disadvantages of hot water heating over steam heating systems.

Hot Water Heating Systems Test Answers

1. A
2. C
3. A
4. B
5. A
6. B
7. C
8. C
9. C
10. B
11. C
12. A
13. C
14. C
15. A
16. B
17. C
18. A
19. B
20. A
21. See text.

22. (1) With a gravity circulation system, large pipe sizes are needed in order to keep resistance to flow to a minimum.
    (2) Circulation is difficult to maintain to radiators on the same level as the boiler in a gravity circulation system.
    (3) There is a slow response to changes in heat demand in a gravity circulation system.
    (4) The maximum water temperature is limited to approximately 170 degrees F.

23. Advantages

1. The temperature of the supply water can be varied in relation to the changing outdoor temperature much more readily than steam temperature can be varied. This allows for variations in load without shutting off and opening up the supply to the radiators.

2. A hot water boiler is smaller and more compact than a steam boiler of the same output, since no boiler steam space is required. In addition, pipe sizes are generally smaller in a hydronic system than in a steam system and fewer and less expensive fittings are required.

3. The piping pitch or slope is not as critical in a forced circulation hydronic system as in a steam system where proper drainage of condensate is important.

4. Maintenance costs are usually less in a hydronic system, due to the fact that traps are not required and also because there is less corrosion in the piping.

Disadvantages

1. When a hydronic system is used in a high multi-story building and the boiler has to be located in the basement, the boiler must be designed to withstand high pressure due to the high head of water in the system.

2. In a large hydronic system, considerable power is required to circulate the water.

3. There is a greater danger of damage due to freezing in a hydronic system.

4. If a leak does occur more damage will result with a hydronic system than with a steam system.

Competency:

1. Explain the basic principles involved in hydraulic system operation.
2. Describe the advantages and disadvantages of a hydraulic system.
3. Summarize safety practices for working on hydraulic systems.
4. Explain how the principles of pressure and flow are used in hydraulic systems.
5. Identify hydraulic system symbols.

Instructional Objectives:

1. State Pascal's Law.
2. Define pressure.
3. List advantages and disadvantages of a hydraulic system.
4. Name six hazards to safety when working with hydraulic systems.
5. List five safety practices when working on hydraulic systems.
6. Define what is meant by conservation of energy.
7. Explain what a prime mover is.
8. Calculate pressure when given force and area.
9. Name the output and input components of a hydraulic system.
10. Identify the characteristics of petroleum oil which make it suitable as a hydraulic fluid.
11. Estimate the pressure at the bottom of a column of oil.
12. State what is definitely known about the pressure on opposite sides of an orifice when oil is flowing through it.
13. Describe the function and operation of the pump in a hydraulic system.
14. Explain how pressure is created in a hydraulic system.
15. State why loss of pressure is usually not a symptom of pump malfunction.
16. State the formula for figuring pressure developed when moving a load with a cylinder.
17. Identify what determines the speed of an actuator.
18. Explain the relationship between fluid, velocity, and friction in a pipe.
19. Outline the relationship between pressure, force, and area in a hydraulic system.
20. Describe how the concepts of work and power are used in a hydraulic system.
21. Identify the components of a basic hydraulic circuit.
22. Distinguish between a hydrodynamic and a hydrostatic device.
23. List two ways which create a tendency for a liquid to flow.
24. Explain the meaning of a pressure "head."
25. Determine atmospheric pressure in psia, psig, inches of mercury, and feet of water.
26. Name two ways to measure flow.
27. Explain what happens when liquid is subject to different pressures.
28. Describe how pump working pressure is determined.
29. Define laminar flow.
30. Identify causes of turbulent flow.
31. State Bernoulli's theorem.
32. Name three kinds of working lines and tell what each does.
33. Identify two forms of energy found in the hydraulic fluid.

34. Match terms associated with fundamentals of hydraulics with their correct definitions.
35. Select statements concerning the power transfer in a hydraulic system.
36. Draw a block diagram of a simple hydraulic system.
37. Draw a symbolic diagram of a simple hydraulic system.

Learning Activities:
1. Read Chapters 1 and 2 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units I and II in Hydraulics.
3. Complete the Review Questions at the end of Chapters 1 and 2 in the Industrial Hydraulics Manual.
4. View the videotapes "The Physical World of a Machine" and "Hydraulic Transmission of Force and Energy" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.
6. Complete Assignment Sheet 1, "Draw a Block Diagram of a Simple Hydraulic System."
7. Complete Assignment Sheet 2, "Draw a Symbolic Diagram of a Simple Hydraulic System."

Evaluation/Checkout:
1. Submit your answers to the Review Questions.
2. Submit Assignment Sheets 1 and 2.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
Several of the companies that manufacture Hydraulics Trainers are listed below.

Lab-Volt Systems
5785 Pembroke Drive
Madison, WI 53711
Contact Mark Hillerns (District Sales Supervisor)
(608)273-1152

Lab-Volt has a variety of hydraulics training systems available. Their fluid power training equipment provides hands-on experience using industrial-rated components and devices designed specifically for training purposes. It is adaptable to the learning needs of the student and the curricular goals of the instructor. Lab-Volt has made its fluid power hardware safe for student use. Safe voltage and pressure levels are used throughout the fluid power program. Safety guards and shields cover moving machinery wherever a hazard exists. Lab-Volt equipment is protected against common forms of student abuse and is designed for quick setup and cleanup. Training benches are rugged and adaptable, constructed of welded steel and mounted on swivel-base castor wheels for added ease of mobility. The system conveniently plugs into a regular wall outlet for power. The modular design of the fluid power systems allows for future updating and expansion for either individual experimentation or group demonstration. Components are stored at the front of the benches and are protected by lockable transparent doors. Interconnection between hydraulic components is accomplished by the use of double-check quick-disconnect fittings. In the basic hydraulics and pneumatics training systems, many components are constructed of clear acrylic to allow students to view working hydraulic and pneumatic circuits. The systems aid students in observing and tracing the fluid flow.

Festo Corporation
395 Moreland Road
Hauppauge, NY 11788
(516)435-0800

The Festo Learning System combines industrial components, patented teaching assemblies and classroom proven courseware to give you everything you need to help students prepare to deal with today's Control and Power Technologies. Coupled with an extensive collection of texts and support material such as video tapes and multi-color overhead transparency sets, the system provides a full set of resources to build your teaching capabilities in:

- -- Pneumatics
- -- Electro-Pneumatics
- -- Electro-Hydraulics
- -- Proportional Hydraulics
- -- Programmable Logic Controllers

The system's modular design allows for exact tailoring to your needs. Hardware: All Festo Didactic training assemblies start with actual industrial components. Each assembly includes the component, information such as circuit diagrams and industrial symbols, and prefitted connections, filters, etc. The patented Festo hardware system makes assembling power and control circuits easy, and so the student can focus on learning.

Courseware: Each Learning System module is based on hands-on exercises. The student learns a concept, and applies it in a real situation. Courseware is keyed to the hardware sets in the system and all modules are compatible. That means you can gear the program directly to your curriculum requirements.

Hampden Engineering Corporation
P.O. Box 563
East Longmeadow, MA 01028-0563
Contact Sheldon Shattuck
(413)525-3981

The Fluid Power Learning System acquaints students with the principles and practices of power transfer through the media of liquid and air. The Hampden Fluid Power Learning System consists of basic hydraulics, advanced hydraulics, electrohydraulics, basic pneumatics, and fluidics.

Vickers Technical Training Center
1332 Anderson Road
Clawson, MI 48017
(313)280-3381

Vickers Fluid Power Trainer's components are standard industrial units which students will subsequently encounter "on the job." Rugged construction and high performance capability assure long-term, trouble-free operation. Components can be interconnected to demonstrate a wide variety of basic hydraulic functions and circuits. Some examples are: reciprocating cylinders (both vertically and horizontally); hydraulic motor rotation; regenerative circuit; sequencing operations; traverse and feed circuits; meter in, meter out and bleed off speed controls. Valving in pump inlet line permits demonstration of cavitation and aeration and their resulting effects.

By-pass valve from pump outlet to reservoir allows low pressure start-up and gradual increase of pressure.

Conveniently located work shelf provides additional area where other components can be located for additional experiments, making circuit possibilities almost unlimited.

Parker Hannifin Corporation
Fluidpower Training
17325 Euclid Avenue
Cleveland, OH 44112
(216)531-3000

Parker Portable Hydraulic Trainer is designed to be a tool for learning hydraulic technology principles and circuitry. It has been engineered for ruggedness, portability, and ease of operation. The unit is completely self-contained and operates on standard 115 Volt A.C. single phase outlet electrical power. The components on the trainer are all industrial grade components, the very same components used in industry every day. This "real world" approach allows the student to learn what those components look like as well as how they operate. All necessary connections are made with hoses and quick disconnects. No tools are required to arrange circuits. Simply plug in the components needed to arrange a circuit. All the hoses are stored in a rack on the rear of the unit. The design concept of the portable hydraulic trainer is based on Parker's long term experience in designing, manufacturing and servicing fluidpower components worldwide.

Learning Material:

1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.

3. A copy of each Assignment Sheet and answers to the review questions is included with this unit.
4. Test questions are included in the Hydraulics text and also questions are available based on the Industrial Hydraulic Technology videotape series.

Audio-Visual Material:

1. The videotapes "The Physical World of a Machine" and "Hydraulic Transmission of Force and Energy" are part of the Industrial Hydraulic Technology Series from Parker Hannifin. This series consists of thirteen videotapes, and an instructor's guide. Student texts, final exams, and 253 transparencies are also available. Their address is given above.

   In "The Physical World of a Machine," the relationship of physics to hydraulics is discussed and various means of transmitting energy are explored. Force, resistance, energy, work, power and other relevant terms are also explained.

   "Hydraulic Transmission of Force and Energy" gives general background information on understanding hydraulic systems. It explores in detail the basic workings of hydraulics with emphasis on force and energy transmission.

Resources:

1. Books:
   A. Esposito, A. Fluid Power with Applications, 2nd Edition. Englewood Cliffs, New Jersey: Prentice-Hall, 1988.
   B. Stewart, H. and Storer, J. Fluid Power. Mission Hills, California: Glencoe Publishing Company, 1980.
   C. DeCarlo, J. Fundamentals of Flow Measurement. Research Triangle Park, North Carolina: Instrument Society of America, 1984.
   D. Wolansky, W. Nagohosian, J., and Henke, R. Fundamentals of Fluid Power. Prospect Heights, Illinois: Waveland Press, 1986.
   E. Pippenger, J. and Hicks, T. Industrial Hydraulics. New York: McGraw-Hill, 1979.
   F. Industrial Fluid Power, Vol. 1,2, and 3. Dallas, Texas: Womack Education Publications, 1972.
   G. Fluid Power in Plant and Field. Dallas, Texas: Womack Educational Publications, 1978.
   H. Practical Fluid Power Control. Dallas, Texas: Womack Educational Publications, 1971.
   I. ISO Fluid Power Graphics Symbols. Cleveland, Ohio: Penton Publishing Company, 1981.
   J. Simon, A. Basic Hydraulics. New York: Wiley, 1981.
   K. Simon, A. Practical Hydraulics. New York: Wiley, 1981.
   L. Basic Hydraulics. Barrington, Illinois: TPC Training Systems, 1981.
   M. Hydraulic Troubleshooting. Barrington, Illinois: TPC Training Systems, 1974.

N. Stewart, H. Pneumatics and Hydraulics. New York: Macmillan Publishing Company, 1987.
O. Sullivan, J. Fluid Power: Theory and Applications. Englewood Cliffs, New Jersey: Prentice-Hall, 1989.
P. Stewart, H. Pumps. New York: Macmillan Publishing Company, 1984.
Q. Henke, R. Fluid Power Systems and Circuits. Cleveland, Ohio: Penton Publishing Company, 1983.
R. Johnson, J. Electrohydraulic Servo Systems. Cleveland, Ohio: Penton Publishing Company, 1977.
S. 1988/1989 Fluid Power Handbook and Directory. Cleveland, Ohio: Penton Publishing Company, 1988.
T. Frankenfeldt, T. Using Industrial Hydraulics. Cleveland, Ohio: Penton Publishing Company, 1986.
U. Valves for Air and Oil Circuits. Cleveland, Ohio: Penton Publishing Company, 1975.
V. AMATROL has several manuals available that deal with hydraulics. Their address is: P.O. Box 2697, Jeffersonville, IN 47131, (812)288-8285.
W. Vickers has the following manuals available: Mobile Hydraulics Manual, Hydraulic Pumps and Motors, and Practical Hydraulics. Contact: Vickers Technical Training Center, 1332 Anderson Road, Clawson, MI 48017, (313)280-3381.
X. Parker Hannifin has the following manuals available: Industrial Hydraulic Technology, Analyzing Hydraulic Systems, Fluid Power 1, Fluid Power 2, Industrial Hydraulic Technology Lab Manual, Design Engineers Handbook, and Troubleshooting Hydraulics. Contact: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland, OH 44112, (216)531-3000.
Y. Hydraulics Workbook. Hauppage, New York: FESTO Corporation, 1982. (Their address is 395 Moreland Road, Hauppage, NY 11788 (516)435-0800).

2. Pamphlets:
   A. DECCA Valves Corporation has a catalog available on fluid control valves. Their address is: 1631 Tenth St., Santa Monica, CA 90404.

3. Audio-Visual Materials:
   A. "Fluid Power Systems-1: Hydraulics" is a videotape available from NUS Training Corporation.
   B. "Hydraulic Fittings" and "Preventive Maintenance of Hydraulic Systems" are videotapes available from Marshall Maintenance Productions.
   C. "Threaded Fasteners," "Tube Fittings," "Hydraulic Systems Maintenance," "Hydraulic Systems Troubleshooting," and "Preventing Hose and Coupling Failures" are videotapes available from Industrial Training, Inc.

D. "Hydraulics" is a videotape available from FESTO Corporation. They also have available a Hydraulics Transparency set, a Magnetic Symbol Set for hydraulic circuits, and fully-operational transparent models which, with the use of an overhead projector, can be projected onto a screen. Their address is given above.

E. "Hydraulic Systems" is a series of nine videotapes available from Industrial Training Corporation.

F. "Introduction to Hydraulics Technology" is a series of eight videotapes available from Vickers Technical Training Center. Also available are a slide/tape presentation entitled "A Better Way," a series of thirteen videotapes on product repair and testing of various pumps and valves, hydraulic cutaway components, color slides to accompany the Industrial Hydraulics Manual, a hydraulics symbols template, and a cylinder calculator (slide rule). Their address is given above.

G. "Hydraulics" is a series of eight videotapes available from Video Training Resource, Inc.

H. Parker Hannifin has available a set of transparencies to accompany their manual, a hydraulic cylinder slide rule, a hydraulic filter media selection slide rule, and a hydraulic template. Their address is given above.

Assignment Sheet 1

Draw a Block Diagram of a Simple Hydraulic System

Draw a block diagram of a simple hydraulic system showing a reservoir, pump, valves, lines, and actuator. Designate flow direction by drawing arrows in the lines.

Assignment Sheet 2

Draw a Symbolic Diagram of a Simple Hydraulic System

Draw a symbolic diagram of a simple hydraulic system show a reservoir, pump, valves, lines and actuator. Designate flow direction by drawing arrows.

Answers to Review Question - Chapter 1

1. Pressure applied on a confined fluid is transmitted undiminished in all directions and acts with equal force on equal areas and at right angles to them.

2. Force on a unit of area, pounds per square inch.

3. A = 20 inches square, $\frac{1000 \text{ lbs.}}{20'' \text{ sq.}}$ = 50 lbs. per square inch.

4. Energy can neither be created nor destroyed.

5. Pump, actuator.

6. The power source.

7. Variable speed, reversible, overload protection, small packages, can be stalled.

8. Greek word hydor, meaning "water" and aulos, meaning "pipe."

9. Oil transmits power readily and is only very slightly compressible. Lubricating ability is most desirable.

10. .4 psi per 1 foot oil column, so 20' x .4 = 8 psi.

11. In order for oil to flow through an orifice, there must be pressure difference.

12. 14.7 psia.

13. For one thing, liquids vaporize in a vacuum. This puts gas bubbles in the oil, impairs the operation of the pump and reduces its life.

14. The sole purpose of a pump is to create flow.

15. A pump can be worn, losing nearly all of its efficiency, and pressure still can be maintained.

16. Pressure is caused by a resistance to flow.

17. When resistances to flow are connected in series, the pressures add up. The pressure normally required to open each valve plus back pressure from the valves downstream.

Example:	1st check	+	2nd check	+	3rd check	=	Total at pump
	200 psi		200 psi		200 psi		600 psi

18. $P = \frac{F}{A}$
    P = pressure in psi
    F = force in pounds
    A = area in square inches

19. $F = P \times A$

20. $\text{Speed} = \frac{\text{volume/time,}}{\text{area}} \quad \frac{\text{volume/time}}{\text{speed}} = \text{Area}$

21. The velocity of fluid varies inversely with the square of the inside diameter (halving the diameter decreases the area to 1/4 and quadruples the oil velocity).

22. Whenever a force or push is exerted through a distance, work is done (Work = Force x Distance). Work is usually expressed in foot pounds. (The rate of doing work is called power. $\text{Power} = \frac{\text{force x distance}}{\text{time}}$ or $\frac{\text{work}}{\text{time}}$).

23. $\text{Power} = \frac{\text{Gallons}}{\text{Minutes}} \times \frac{\text{Pounds}}{\text{Square inches}}$ OR $\text{Hp} = \frac{\text{GPM x PSI}}{1714}$

24. Selection of an actuator.

25. Pumps are usually rated in gallons per minute. It will be necessary to divide 231 into the cubic inches per minute needed in a system (231 = cubic inches per gallon).

26. $A = .7854 \times d^2$, $A = .7854 \times 25^2 = 19.635$ sq. in.

27. Protects the system from overloads by diverting pump delivery to reservoir when pressure reaches its setting.

28. Controls the direction of oil flow in the system.

Answers to Review Questions - Chapter 2

1. A hydraulic device which uses the impact or kinetic energy in the liquid to transmit is called a hydrodynamic device.
2. When the device is operated by force applied to a confined liquid, it is called a hydrostatic device.
3. A mechanical pump or the weight of the fluid.
4. "Head" is used to describe pressure, no matter how it is created. Can be expressed as psi.
5. 14.7 psia, 0 psig, 30 inches of mercury, and 34 feet of water.
6. By atmospheric pressure.
7. 30 psig + 14.7 psia = 44.7 psia.
8. Velocity and flow.
9. 1 g.p.m. = 231 cubic inches/min. 5 x 231 = 1155 cubic inches/min.
10. The fluid will seek an equal pressure level.
11. Pressure needed to move the load, plus the pressure required to move the fluid mass and to overcome friction.
12. Laminar flow is in straight parallel paths, and friction is minimized.
13. Abrupt changes in direction or cross section, or too high velocity.
14. Kinetic and potential energy.
15. The sums of the pressure energy and kinetic energy at various points in the system must be constant if flow rate is constant.
16. Working line, pilot line, and drain line.
    Working line carries the main flow of the system.
    Pilot line carries fluid that is used to control the operation of a valve.
    Drain line carries leakage oil back to the reservoir.
17. The circle is the basic symbol for rotating components.
18. Single envelopes.
19. When lines terminate below the fluid level in the reservoir.
20. Two, the relief valve has one.

Competency:

1. Describe the purpose and characteristics of hydraulic fluid.
2. Explain how reservoirs and filters are used in a hydraulic system.
3. Identify components of reservoirs and filters.
4. Demonstrate the ability to clean and inspect a reservoir.

Instructional Objectives:

1. List four primary functions of the fluid in hydraulic systems.
2. Name four quality properties of a hydraulic fluid.
3. Define viscosity.
4. Identify the effects of temperature on the viscosity of hydraulic fluids.
5. Describe what the viscosity index is.
6. Name several catalysts to oxidation of hydraulic oil.
7. Name common additives in hydraulic systems.
8. Define demulsibility.
9. List three factors that determine the properties of a hydraulic oil.
10. List three basic types of fire-resistant hydraulic fluid.
11. List six safety rules to remember when working with hydraulic fluid.
12. Define reservoir.
13. Identify two types of reservoirs.
14. List three functions of a reservoir.
15. Identify the parts of a properly designed, vented reservoir.
16. Identify the parts of a properly designed, pressurized reservoir.
17. Demonstrate the ability to clean and inspect a vented reservoir.
18. List the functions of a filter.
19. Identify the effects of contaminants in the hydraulic system.
20. Define mesh and micron ratings.
21. Name three possible locations for a filter.
22. Identify types of filter circuits.
23. Distinguish between surface filters and depth filters.
24. Identify factors used in specifying a filter.
25. Name three different types of filtering material.
26. Define full-flow.
27. Explain the purpose of an indicator type filter.

Learning Activities:

1. Read Chapters 3 and 5 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units III and VI in Hydraulics.
3. Complete the Review Questions at the end of Chapters 3 and 5 in the Industrial Hydraulics Manual.
4. View the videotape "Fluids, Reservoirs, Coolers, and Filters" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Clean and inspect a vented reservoir.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. A job sheet for the exercise for this unit is in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. A copy of the answers to the review questions is included with this unit.
4. Test questions are included in the Hydraulics text and also questions are available based on the Industrial Hydraulic Technology videotape series.

Audio-Visual Material:

1. The videotape "Fluids, Reservoirs, Coolers, and Filters" is part of the Industrial Hydraulic Technology Series from Parker Hannifin. This series consists of thirteen videotapes and an instructor's guide. Student texts, final exams, and 253 transparencies are also available.

   "Fluids, Reservoirs, Coolers, and Filters" covers the best ways to clean and cool a hydraulic system. It gives an overall view of hydraulic fluids, reservoirs, filters, and various coolers. Maintenance and upkeep of filters are also featured.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 3

1. A. Power transmission
   B. Lubrication
   C. Sealing
   D. Cooling

2. A. Prevent rust
   B. Prevent formation of sludge, gum, and varnish.
   C. Depress foaming
   D. Compatibility with seals and gaskets

3. A. Viscosity is the measure of the fluid's resistance to flow; or an inverse measure of fluidity.
   B. (SUS)

4. A. By cold; at zero degrees the 50 VI oil is thick. Its SUS rate is 12,000.
   B. By heat; at 210 degrees the 50 VI oil is thinner. SUS rate is 41.

5. A. High temperature caused by friction.
   B. High resistance to flow.
   C. Increased power consumption due to frictional loss.
   D. Internal leakage increases.

6. A. Is a relative measure of a fluid's resistance to viscosity change with temperature change.
   B. When the equipment operates in temperature extremes, a high VI is desirable.

7. Petroleum oil has excellent lubricity.

8. A. Temperature
   B. Pressure
   C. Contaminants

9. By additives that "plate" on the metal surface to prevent their being attacked chemically.

10. The ability to separate out water in the oil.

11. A. The type of crude oil used.
    B. The degree and method of refining.
    C. The additives used.

12. A. Water - Glycols
    B. Water - Oil Emulsions
    C. Synthetics

13. Synthetic fluids

14. Synthetic fluids

15. Care so that pump inlets do not cause conditions of pump cavitation when used.
16. Keeping the fluid clean and free from moisture.

Answers to Review Questions - Chapter 5

1. A. Storehouse for the fluid.
   B. Place for air to separate out of the fluid.
   C. Dissipate any heat that is generated in the system.

2. At the lowest point in the system's tank.

3. Through a sight glass or over a dipstick.

4. To maintain atmospheric pressure in the tank whether the tank is full or empty.

5. Is used to separate the pump inlet from the return line so that the same fluid cannot recirculate continuously.

6. Prevents the line opening from "bottoming" in the tank and cutting off the flow.

7. 10 gallons or 15 gallons.

8. Filter - A device whose primary function is the retention of contaminates from the fluid.
   Strainer - A course filter.

9. The sieve No. 140 = 105 microns; the sieve No. 200 = 74 microns. A sieve No. 170 is about 90 microns.

10. One micron is .000039 inches big.

11. Is the largest opening in the filter. That is, no particles above a given size will be allowed to circulate in the system.

12. The inlet, the pressure lines, and return lines.

13. The surface type, with closely woven fabric or treated paper with pores to allow fluid to flow through.

14. That all the flow goes through the filter element.

15. So the operator can see when the element needs cleaning without checking the timetable or checking the pressure-drop across the filter.

Competency:

1. Describe the types of pipe/tubing and fittings used to carry hydraulic fluids.
2. Describe the types of seals and seal materials required for hydraulic application.
3. Explain how leaks can be prevented in hydraulic systems.
4. Demonstrate the ability to work with pipe/tubing/hose used in hydraulic systems.
5. Demonstrate the ability to install seals for hydraulic components.

Instructional Objectives:

1. Describe how pipe size is specified.
2. Identify the schedule number of standard pipe.
3. Identify the types, construction, and size of steel tubing.
4. Identify types of fittings used in hydraulic systems.
5. List the advantages of tubing over pipe.
6. Identify types of fittings commonly used with tubing.
7. List characteristics of hydraulic hose.
8. Identify types of hose ends used in hydraulic systems.
9. Name two reasons for pipe support.
10. List factors to consider when routing tubing in hydraulic systems.
11. List conditions to avoid when routing hydraulic hose.
12. Demonstrate the ability to replace a reusable hose end.
13. Define positive seal.
14. Describe two types of leakage paths in hydraulic systems.
15. Explain the meaning of static sealing application.
16. Identify types of sealing devices used in hydraulic systems.
17. List types of seals and their applications.
18. Identify types of seal construction and when each type is used.
19. Define elastomer.
20. Identify seal materials.
21. List factors to consider concerning seal material.
22. Name three general ways to prevent leakage.
23. Explain the meaning of back-mounting.
24. List five operating factors that affect seal life.
25. Demonstrate the ability to install an O-ring.
26. Demonstrate the ability to install a seal.
27. Demonstrate the ability to install a packing.
28. Demonstrate the ability to cut, flare, bend, swage, and ream tubing.

Learning Activities:

1. Read Chapter 4 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units IV and V in Hydraulics.
3. Complete the Review Questions at the end of Chapter 4 in the Industrial Hydraulics Manual.
4. Read Know Your Hoses, Tubing, and Fittings.
5. View the videotapes "Tube Fittings," "Preventing Hose and Coupling Failures" and "Threaded Fasteners" (Industrial Training, Inc.).

6. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:
1. Demonstrate the ability to replace a reusable hose end.
2. Demonstrate the ability to install an O-ring.
3. Demonstrate the ability to install a seal.
4. Demonstrate the ability to install a packing.
5. Demonstrate the ability to cut, flare, bend, swage, and ream tubing.

Evaluation/Checkout:
1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises are in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. Know Your Hoses, Tubing and Fittings. Cleveland, Ohio: Penton Publishing Company, 1983.
4. A copy of the answers to the review questions is included with this unit.
5. Test questions are included in the Hydraulics text.

Audio-Visual Material:
1. The videotapes "Threaded Fasteners," "Tube Fittings," and "Preventing Hose and Coupling Failures" are available from Industrial Training, Inc. The tapes are designed to train workers in the selection and proper use of fasteners, tube fittings, hoses, and hose couplings. The basics of cutting, bending, and routing of hydraulic lines are also covered in the series.

Resources:

1. A listing of books and audiovisual material is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 4

1. Pipe and pipe fittings are classified by nominal size and wall thickness.

2. Schedule 40.

3. Joints are sealed by an interference fit between the male and female threads.

4. Tubing can be bent, is easier to work with, and can be used over and over.

5. Outside diameter.

6. Fittings seal by metal-to-metal contact, o-rings, and comparable seals.

7. With layers of wire braids, and rubber, and braided fabric.

8. Sand blasting, de-greasing, and pickling.

9. A. Vibration B. Shock

10. Prevents even a minute amount of fluid from getting past.

11. A seal that is compressed between two rigidly connected parts.

12. A. O-ring seals B. Cup seals

13. Rotating shafts.

14. Where a high pressure seal is required around a rotating shaft.

15. Synthetic rubber seals.

16. 200 degrees F.

17. Silicone has a wider temperature range but doesn't work for reciprocations.

18. A. Proper installation
    B. Control of operating condition
    C. Design to minimize the possibility of leaks

19. Back-mounting of valves with all pipe connections made permanently to a mounting plate.

20. A. Temperature
    B. Pressure
    C. Lubrication

Competency:

1. Explain the purpose of hydraulic actuators and identify the different types.
2. Indicate how a hydraulic actuator is chosen for a particular application.
3. Demonstrate the ability to repair a hydraulic cylinder.

Instructional Objectives:

1. Describe the operation of a hydraulic cylinder.
2. Distinguish between the operation of a single-acting and double-acting cylinder.
3. Identify types of double-acting cylinders.
4. Identify the parts of a single-acting cylinder.
5. Identify the parts of a double-acting cylinder.
6. List sources of common failures of hydraulic cylinders.
7. Given a formula, calculate the force output of a hydraulic cylinder.
8. Given a formula, calculate the speed of a hydraulic cylinder.
9. Given a formula, calculate the power output of a cylinder.
10. Given a formula, calculate the flow rate required to move a cylinder a given distance in a given time.
11. Demonstrate the ability to disassemble, inspect, and reassemble a hydraulic cylinder.
12. Demonstrate the ability to test a cylinder for internal and external leakage.
13. Define displacement and torque ratings of a hydraulic motor.
14. Name three kinds of hydraulic motors.
15. Contrast gear motors with vane motors in terms of how torque is developed in each.
16. Given a formula, calculate hydraulic motor load torque.
17. Given a formula, calculate the displacement of a hydraulic motor.
18. Given a formula, calculate the speed of a hydraulic motor.
19. Given a formula, calculate hydraulic motor inlet pressure.
20. Given a formula, calculate hydraulic motor input and output power.
21. Given a formula, calculate motor overall efficiency.
22. Explain the operation of a gear motor.
23. Explain the operation of vane motors.
24. Name three types of piston motors.
25. Explain the operation of an in-line axial piston motor.
26. Compare the efficiency of the various types of hydraulic motors.

Learning Activities:

1. Read Chapter 6 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units IX and X in Hydraulics.
3. Complete the Review Questions at the end of Chapter 6 in the Industrial Hydraulics Manual.
4. View the videotapes "Hydraulic Actuators" and "Hydraulic Motors" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Demonstrate the ability to disassemble, inspect, and reassemble a hydraulic cylinder.
2. Demonstrate the ability to test a cylinder for internal and external leakage.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises are in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task. Job Sheet 1 and Job Sheet 1A are similar activities. Either one can be assigned. A copy of Job Sheet 1A is included with this unit.

Learning Materials:

1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. A copy of the answers to the review questions is included with this unit.
4. Test questions are included in the Hydraulics text and also questions are available based on the Industrial Hydraulics Technology videotape series.

Audio-Visual Material:

1. The videotapes "Hydraulic Actuators" and "Hydraulic Motors" are part of the Industrial Hydraulic Technology Series from Parker Hannifin. This series consists of thirteen videotapes and an instructor's guide. Student texts, final exams, and 253 transparencies are also available.

   "Hydraulics Actuators" re-introduces cylinders. How a cylinder develops force, how a cylinder's stroke and volume are related and how a piston's rod speed is calculated are considered. Hydraulic motor operation is also covered in this program.

In "Hydraulic Motors," the workings of hydraulic motors are explained. The various types of motors are discussed and compared against each other for different applications. Technical terms are defined and reviewed.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 6

1. In single-acting, oil flows into only one side of the cylinder, and the cylinder is retracted by gravity or a spring.
   In double-acting, oil flows into one side to extend the cylinder, and the cylinder is retracted by oil flow into the other side of the cylinder.

2. 220.70 inches per minute.

3. 14,137.2 lbs.

4. 2,000 psi.

5. Displacement is the amount of fluid which the motor will accept in turning one revolution.

   Torque is the force component of the motor's output, its turning or twisting effort on the load.

6. 3.33 lb. in./100 psi.

7. 2500 psi.

8. Two shuttle valves in the pressure plate interconnect passages to maintain this pressure no matter which port is pressurized.

9. Pivoted rocker arms are attached to the rotor and force the vanes outward against the elliptical cam ring. In high-performance vane motors, the vanes are held out against the ring by coil springs.

10. Torque is proportional to the area of the pistons and is a function of the angle at which the swash plate is positioned.

11. Any load increase is accompanied by corresponding pressure increase. The control then automatically adjusts the yoke so that the torque increases under a heavy load.

12. The piston motors.

JOB SHEET 1A - DISASSEMBLE, INSPECT, AND REASSEMBLE A HYDRAULIC CYLINDER

Objective - To disassemble, inspect and reassemble a hydraulic cylinder according to manufacturer's specifications.

Reference - JARP Industries, Inc., Wausau, Wisconsin
Cylinder Assembly No. 12066B

Equipment - One hydraulic cylinder (2500 psi). A bench with a suitable vise and the following tools will be used: strap wrench, screw driver, torque wrench, dial caliper, internal micrometer, socket wrench set, socket head wrench set, open end wrench set, and O-ring pick.

SERVICE PROCEDURES

Study blueprint (#120066B) and bill of material on cylinder assembly from JARP Industries.

DISASSEMBLY - SAFETY GLASSES MUST BE WORN. When tearing the cylinder down, make sure any exposed threads are covered with tape. This will prevent seals from being cut when rod is being removed through the rod gland. IMPORTANT!! Lay out on the bench in order all the parts as the cylinder is being disassembled.

Rod Gland - This is a good time to check rod gland seals and the rod gland itself for wear. With the use of an internal micrometer, you can check both ends of the rod gland for out-of-round. If the micrometer shows more than .003 of an inch out-of-round, the gland should be replaced. Also by checking both sides of the rod gland, you can tell if the cylinder is aligned correctly. This can be done by observing the front and back end of the rod gland. If it is worn from the right side in the front to the left side in the back, or vica versa, it is out of alignment and must be realigned. The cylinder mount should be checked to make sure it is in alignment with the machine it is to activate.

Seals - The seals should be checked at this time. They consist of a wiper seal and one or more O-rings. During reassembly, care must be taken when installing the cylinder rod that they are not nicked.

Piston Rod - The rod should be checked for weld splatter and scratches. These can be removed with a fine file and then polished with crocus cloth. This must be done to protect the rod gland seals.

The piston rod may be held to the piston by threads and a nut which uses a sealing material called Loctite. Loctite can be softened so that it can be removed by the use of an electric hot plate and Crisco cooking oil. Heat the oil to 400 degrees F. because it requires that much heat to break the bond. Make sure that eye and hand protection are used when working with the high temperature oil. Severe burns could result if proper care is not taken.

When Loctite is not used to secure the nut to the rod shaft, the nut must be torqued to the manufacturer's specifications. This is stated in ft. lbs. and a good torque wrench should be used.

Cylinder Bore - The cylinder should be checked for dents, bulges, and dings. Do not try to repair by welding for the excessive heat will cause the cylinder to go out-of-round. Scratches and scoring if not in excess of .010 inches may be repaired by honing. These kits are available in auto repair shops and are driven with a drill motor. If there are some scratches which will not hone out when you reach the .010 inches oversize, do not throw the cylinder away. Install new piston seals and test the cylinder for leakage. It is very possible that the seals will form to the remaining scratches and no leakage will occur. If it still leaks, then it is time to replace the cylinder.

Inspection of Seals - Following are some of the reasons seals wear out and need to replaced:

Sticky Seals (Due to excessive heat).
- Buna-N is used up to 165 degrees F. Above this temperature will result in reduced life.
- Viton is used up to 360 degrees F.
- Teflon seals are used up to 450/500 degrees F. (There are new materials coming out everyday. Manufacturer's specifications must be adhered to).
- Incompatible lubrication - Never use brake fluid (castor oil based) with synthetic rubber. Certain greases may not be compatible with synthetics. Certain fire resistant fluids are incompatible (in hydraulics). Polyurethane ester seals are subject to hydrolysis (water based fluids will cause swelling and crumbling).

Dry or Crumbly Seals
- Shelf time is too long before using resulting in insufficient lubrication.

Abraded or Peeled Seals
- Not sized correctly. They are too tight.

Extruded O-rings
- No backup rings, poor design or they were not installed.

Blown Seals
- Improper installation.
- Undersized seals.
- Hydraulic shock.
- Not using correctly designed seals.

REASSEMBLY - With the parts laid out in the exact order they were removed from the cylinder, they are now assembled in reverse order.

Cylinder - The cylinder should be cleaned with a safe cleaning fluid before being put back into operation. This will remove any grinding compound which may be present from the honing process. Trichlorotrifluoroethane does not give off toxic fumes and is safe to use. The cylinder bore should than be coated with a light coating of hydraulic oil for ease of assembly.

Seals - Check to see what type of hydraulic fluid was being used to make sure the seals are compatible. CAUTION: If seals have a lip, make sure the pressure will expand the lip against the cylinder wall.

Back-up Washers - These should be placed on the back side of the O-ring to prevent O-ring seals from extruding over piston walls.

Cylinder Rod - This must be secured to the piston so it does not come loose during operation. When Loctite is used, the threads should be prepared with Locquic primer. Loctite is then put on the threads and secured into the piston. Allow 30 minutes to dry. If temperature in operation is to exceed 200 degrees F., a set screw should also be used. When Loctite is not used the nut must be torqued to the manufacturer's specifications.

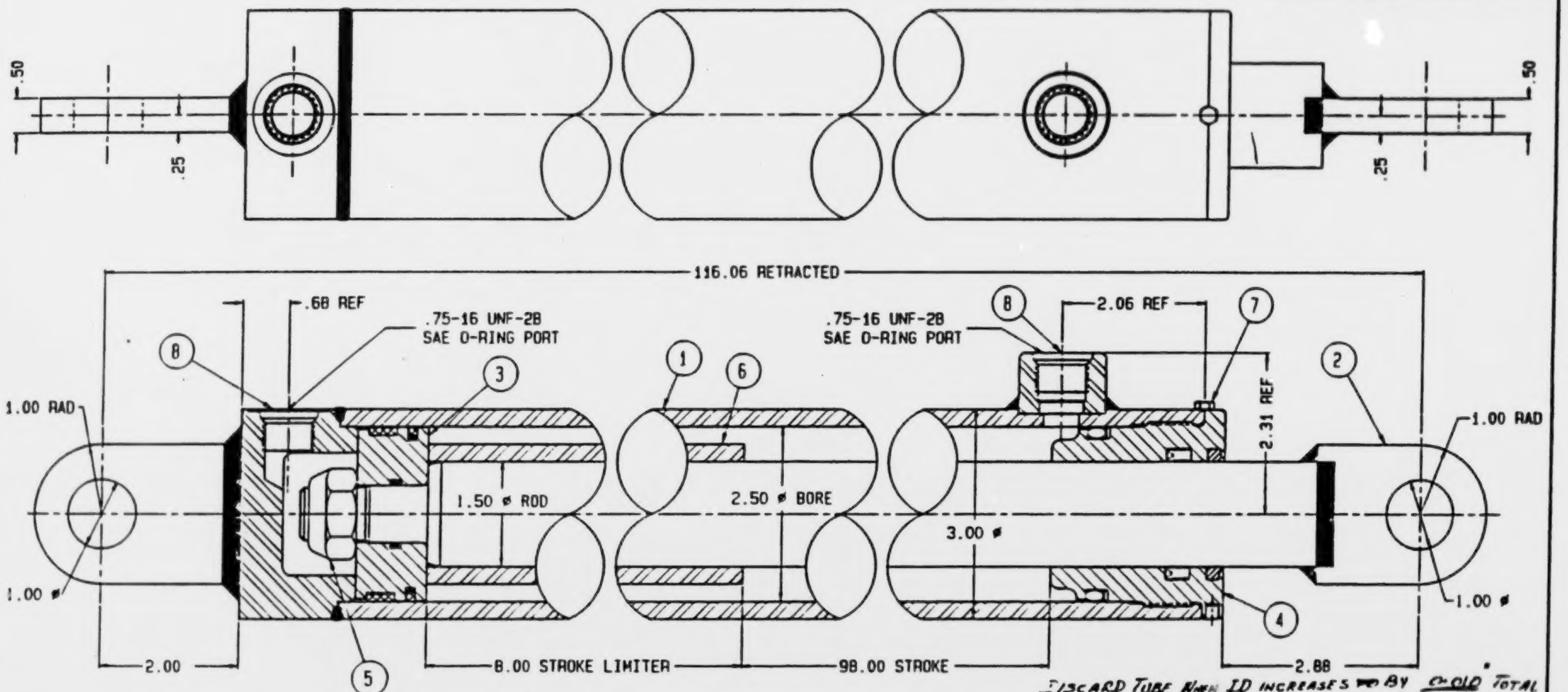
Testing - The cylinder should be leak tested before it is installed back on the machine or putting back on the shelf. Secure the cylinder and test at its operating pressure. It has a safety rating of 4 to 1 but this is used only when testing for bursting by the manufacturer. The reasons for leak testing are: (1) seals with lips installed backwards; (2) back-up rings left out with o-ring seals; (3) clipped seals due to the piston rod thread not being covered when reassembling; and (4) poor alignment when piston is being inserted into the barrel of the cylinder. Testing is done with the use of hydraulic pressure and a needle valve.

Rod End Intensification Test - Install a needle valve on the rod end of the cylinder. Air should be bled out of the cylinder and it must be full of oil with the rod retracted. Pressure should then be applied to the blind end of the cylinder. The rod should extend for a short distance and then stop. If the oil is leaking past the piston seals, the cylinder rod will continue to advance. By observing flow from the needle valve when it is opened enough to stop cylinder rod movement, the amount of leakage can be measured.

It is wise to test the piston at several different places in its lengths of barrel travel. Due to different lengths of stroke on the machine which it operates, you can have uneven wear of cylinder walls. If the rod stops, your repairs are complete. If not, check the four seal applications under testing and when one of these is corrected the problem should be solved.

(Prepared by Ken Spaude - Industrial Pipefitter Apprenticeship Instructor)

BILL OF MATERIAL			
ITEM	DESCRIPTION	PART NO.	QTY
1	BARREL ASSEMBLY		1
2	ROD ASSEMBLY		1
3	PISTON ASSEMBLY	[illegible]	1
4	ROD BEARING ASSEMBLY		1
5	NUT	[illegible]	1
6	STROKE LIMITER		1
7	CAP SCREW	[illegible]	1
8	SHIPPING PLUG	[illegible]	2


.50
.25
.50
.25
116.06 RETRACTED
.68 REF
.75-16 UNF-2B
SAE O-RING PORT
.75-16 UNF-2B
SAE O-RING PORT
2.06 REF
8
3
1
6
8
7
2
1.00 RAD
1.00 RAD
2.31 REF
1.50 ø ROD
2.50 ø BORE
3.00 ø
1.00 ø
1.00 ø
4
5
2.00
8.00 STROKE LIMITER
98.00 STROKE
2.88

DISCARD TUBE WHEN ID INCREASES BY 0.010" TOTAL

OPERATING PRESS = 2500 PSI

LEACH TOP DOOR CYL.
PROJECT 100

NOTES:

1. TORQUE NUT ITEM 5, TO 112 FT/LBS. THD'S MUST BE LUBRICATED WITH CLEAN HYD. OIL.
2. STAMP CYLINDER PER JARP J-103 SPEC.
3. INSTALL ROD BEARING LOCKING SCREW ITEM 7, PER JARP J-105 SPEC.
4. ORDER SEAL KIT NO.
5. PROTECT PORTS FOR SHIPPING ITEM 8.

ROD - NOMINAL OD. $^{+.000}_{-.002}$

PISTON - NOMINAL OD $^{+.000}_{-.010}$

TUBE ID = NOMINAL $^{+.003}_{-.000}$ HONED DIA

PISTON SEALS AS INSTALLED } OD = 2.015" DIA

JARP INDUSTRIES INC.
WAUSAU, WISCONSIN

CYLINDER ASSEMBLY

DRAWN BY	DATE	CHECKED BY	DATE
PETITT	5-5-88		

SCALE	NUMBER
FULL	120066B

$2.500 ^{+.003}_{-.000}$ 2.480

BEST COPY AVAILABLE

Competency:

1. Explain the function and operation of directional controls, pressure controls, and volume controls in a hydraulic system.
2. Determine what type of control is necessary for a particular application.
3. Demonstrate the ability to repair/install hydraulic controls.

Instructional Objectives:

1. Describe the function of a directional control.
2. Identify types of directional control valves.
3. Explain what is meant by finite positioning.
4. Explain the function of a check valve.
5. Distinguish between the operation of a check valve and a spool direction control valve.
6. Describe the operation of a pilot-operated check valve.
7. Name three ways to shift a four-way valve.
8. Describe the flow paths in a directional control valve controlling a cylinder.
9. Distinguish between open-center and closed-center systems.
10. Identify types of actuators for directional control valves.
11. Explain how pilot pressure may be created for an open-center, pilot-operated valve.
12. Describe the function of a pilot choke.
13. Describe the operation of a mechanical servo valve.
14. Describe the operation of a electro-hydraulic servo valve.
15. Identify the primary feature which makes a servo valve different from an ordinary valve.
16. Name three types of pressure control valves.
17. Define cracking pressure.
18. Identify types of pressure relief valves when given a description of their operations.
19. Explain what is meant by venting the relief valve.
20. Describe the operation of "R" type valves.
21. Name three applications of the "R" valve.
22. Name three applications of the "RC" valve.
23. Identify operational characteristics of a pressure reducing valve.
24. List three types of flow control valves.
25. Identify an application for each of the three types of flow control valves.
26. List the two categories of flow control valves.
27. Differentiate between a by-pass and restricted type flow control.
28. Identify operational characteristics of a pressure compensated flow control valve.
29. Identify when temperature compensation might be needed.
30. Name the advantage of the flow control and relief valve over a conventional flow control.
31. Demonstrate the ability to disassemble, inspect, and reassemble a pressure control valve.
32. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve.

33. Demonstrate the ability to disassemble, inspect, and reassemble a flow control valve.

Learning Activities:
1. Read Chapters 7,8,9, and 10 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheet from Unit VIII in Hydraulics.
3. Complete the Review Questions at the end of Chapters 7,8,9, and 10 in the Industrial Hydraulics Manual.
4. View the videotapes "Control of Hydraulic Energy," "Flow Control Valves," "Check Valves, Accumulators and Cylinders," "Directional Control Valves," "Pressure Control Valves," and "Pilot Operated Pressure Control Valves" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:
1. Demonstrate the ability to disassemble, inspect, and reassemble a pressure control valve.
2. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve.
3. Demonstrate the ability to disassemble, inspect, and reassemble a flow control valve.

Evaluation/Checkout:
1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises are in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets and tests.
3. A copy of the answers to the review questions is included with this unit.

4. Test questions are included in the *Hydraulics* text and also questions are available based on the *Industrial Hydraulic Technology* videotape series.

Audio-Visual Material:

1. The videotapes "Control of Hydraulic Energy," "Check Valves, Accumulators and Cylinders," "Flow Control Valves," "Directional Control Valves," "Pressure Control Valves," and "Pilot Operated Pressure Control Valves" are part of the *Industrial Hydraulic Technology Series* from Parker Hannifin. This series consists of thirteen videotapes and an instructor's guide. Student texts, final exams, and 253 transparencies are also available.

   In "Control of Hydraulic Energy," methods of controlling the flow of hydraulic energy are explained. The program also covers control of hydraulic pressure and gives a demonstration of a simple hydraulic system. Terms associated with the pressure side of a system are defined.

   "Check Valves, Accumulators and Cylinders" explains various types of accumulators, check valves, and cylinders as well as demonstrates how each is used. Terms associated with all three are defined and discussed.

   "Flow Control Valves" provides specific information and instruction on the workings of industrial hydraulic flow control valves. The various elements that can affect flow are discussed and demonstrated, and general maintenance tips are outlined.

   "Directional Control Valves" concentrates on two-way, three-way, and four-way directional control valves, how they work and their use in a circuit. Solenoids are discussed and general terms relevant to directional control valves are defined.

   "Pressure Control Valves" demonstrates the uses of the pressure control valve in a hydraulic system. Explanations of what a normally open pressure control valve is and how it works are given, along with definitions of common terms and idioms.

   "Pilot Operated Pressure Control Valves" demonstrates the characteristics of pilot operated valves. It also explains how pilot operated pressure control valves work and shows common applications. Pilot operated relief valves are also covered.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for *Hydraulics*, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 7

1. To control direction of the flow of oil in the system.
2. They control where the oil goes by opening and closing flow paths in definite valve positions.
3. To control reverse flow, a one-way directional valve.
4. In "2C" the pilot pressure required to unseat the poppet must exceed 40 percent of the pressure in the outlet side, whereas "4C" requires 80 percent.
5. Four-way.
6. Air pressure, solenoid, pilot pressure.
7. Spring-offset has two. Spring-centered has one.
8. Both cylinder parts are blocked, but the pressure port is open to tank, permitting two or more valves to be connected in series or tandem.
9. By putting a check valve in the return line.
10. It is a meter-out restriction valve. It is used for slowing down spool travel.
11. It permits the load to creep to its final position. The tapered plunger design has only part of the travel available for control at low flow rates.

Answers to Review Questions - Chapter 8

1. The valve body is connected to and moves with the load.

   The control handle is connected to the valve spool.

2. An electrical signal to a torque motor which directly or indirectly positions a spool valve.

3. The feedback sensing devices. Very accurate control of the position, velocity, or acceleration of an actuator may be obtained.

4. A low-amplitude alternating signal usually 60 cycle supplied to the torque motor in an electro-hydraulic servo valve. It is used to counteract static friction, and provide more dirt tolerance.

5. The flapper type sliding spool is actuated by a pressure difference on the two ends. The jet-type servo valve has a spool that is shifted by a pressure difference with centering springs to oppose the force.

Answers to Review Questions - Chapter 9

1. A. Limiting maximum system pressure.
    B. Regulating reduced pressure in certain portions of a circuit.
    C. Regulating pressure due to change in operating pressure.

2. Between the pressure line (pump outlet) and the reservoir.

3. The pressure at which the valve first begins to divert flow.

4. Due to the fluid lost through the valve before its maximum setting is reached, power is wasted.

5. At any pressure less than the valve setting, the piston is held on its seat by a light spring.

6. The chamber above the piston is "vented" to the tank, so it will open fully at set-back pressure.

7. To release flow (usually directly to the reservoir), to prevent pressure being imposed on the system or portion of the system.

8. A heavier spring is used to permit pressures of 50-70 psi when required for pilot pressure.

9. A. Relief valve
    B. Sequence valve
    C. Unloading valve

10. A. Sequence valve
    B. Counterbalance valve
    C. Brake valve

11. A sequence valve is used to cause actions to take place in a system in a definite order.

12. Externally.

13. It is used to maintain control over a vertical cylinder so that it will not fall freely because of gravity.

14. Senses the pressure from the primary port of the "RC" valve which is connected to the motor exhaust port.

15. "X" type sequence valves.

16. To maintain reduced pressures in certain portions of the system.

17. Pressure reducing valves.

18. Limit maximum pressure, and unload the pump when pressure is reached.

Answers to Review Questions - Chapter 10

1. A variable displacement pump or use a fixed displacement pump and regulate flow with a volume control valve.

2. Meter-in, meter-out, and bleed-off.

3. A. Meter-in - For highly accurate control, used in applications where the load continually resists movement of the actuator.
   B. Meter-out - Is used where the load might tend to "run away."
   C. Bleed-off - The pump operates at the pressure required by the work since excess fluid returns to the tank through the flow control instead of through the relief valve.

4. A non-pressure compensated flow control valve including a check valve permits volume control in one way and free flow in the other direction.

5. A by-pass type has a normally closed hydrostat which opens to direct fluid, in excess of the throttle setting, to the tank. In the restrictor type the hydrostat is normally open and tends to close off blocking all flow in excess of the throttle setting.

6. With pressure compensation, a constant pressure drop is maintained across an adjustable throttle.

7. A thermometer indicates temperature compensation. (See page 10-6).

8. Oil flows more freely when it is hot, constant flow can be maintained by decreasing the size of the throttle opening as the temperature rises.

9. It is a constant flow control over all temperature/pressure differences in a normal operating system. It provides highly accurate control.

10. The throttle spool is linked to the armature of a torque motor and moves in response to signals to the torque motor.

Competency:
1. Explain the function and operation of the various types of pumps used in a hydraulic system.
2. Perform various calculations concerning pump operation.
3. Demonstrate the ability to repair/install hydraulic pumps.

Instructional Objectives:
1. Explain why a centrifugal pump would not be used to transmit pressure.
2. Distinguish between positive and nonpositive displacement pumps.
3. Describe the basic characteristics of positive displacement pumps.
4. Name kinds of positive displacement pumps.
5. Explain what a pump's pressure rating means.
6. State two ways of expressing pump size.
7. Given the formula, calculate pump displacement.
8. Given the formula, calculate pump flow rate.
9. Given the formula, calculate pump input and output power.
10. Calculate pump volumetric efficiency.
11. List the advantages and disadvantages of gear pumps.
12. Identify the operational characteristics of vane pumps.
13. Distinguish between an axial and radial piston pump.
14. Identify the operational characteristics of a radial piston pump.
15. Name two types of axial piston pumps.
16. Describe the construction and operation of axial piston pumps.
17. Identify the operational characteristics of a variable displacement axial piston pump.
18. Identify the parts of a servo-controlled variable displacement pump.
19. Match the components of pressure compensated axial piston pumps with their functions.
20. List four causes of hydraulic pump cavitation.
21. List common causes of hydraulic pump failure.
22. Demonstrate the ability to disassemble, inspect, and reassemble a gear pump.
23. Demonstrate the ability to disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

Learning Activities:
1. Read Chapter 11 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheet from Unit VII in Hydraulics.
3. Complete the Review Questions at the end of Chapter 11 in the Industrial Hydraulics Manual.
4. View the videotapes "Operation at the Suction Side of a Pump" and "Hydraulic Pumps" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.
6. Complete Assignment 1, "Calculate Pump Displacement, Flow Rate, Input and Output Power, and Overall Efficiency."

Application Exercises:
1. Demonstrate the ability to disassemble, inspect, and reassemble a gear pump.
2. Demonstrate the ability to disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

Evaluation/Checkout:
1. Submit your answers to the Review Questions.
2. Submit Assignment Sheet 1.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises are in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. A copy of the Assignment Sheet and answers to the review questions is included with this unit.
4. Test questions are included in the Hydraulics text and also questions are available based on the Industrial Hydraulic Technology videotape series.

Audio-Visual Material:
1. The videotapes "Operation at the Suction Side of a Pump" and "Hydraulic Pumps" are part of the Industrial Hydraulic Technology Series from Parker Hannifin. This series consists of thirteen videotapes and an instructor's guide. Student texts, final exams, and 253 transparencies are also available.

   In "Operation at the Suction Side of a Pump" the importance of hydraulic pump operation on the suction side of a pump is illustrated, and a number of important technical terms are also listed and explained in detail. Cavitation, entrained air, and dissolved air are also covered.

In "Hydraulic Pumps" positive displacement pumps are the focus. Vane pumps, gear pumps, and piston pumps are all covered in detail. Different applications of each are also discussed.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 11

1. A centrifugal pump is used for transfer of fluids where the only resistance encountered is that created by the weight of the fluid itself and friction.

2. They provide a given amount of fluid for every stroke, revolution, or cycle. Their output is independent of outlet pressure making them well suited for use in hydraulic systems.

3. The pressure rating of a pump is determined by the manufacturer. It is what can be expected under specified operating conditions.

4. By displacement or G.P.M.

5. 5 G.P.M.

6. 70% Efficiency

7. They are usually low pressure units because of the shaft side loading.

8. Vane pumps compensate for wear by the vanes moving farther out of their slots. They are reliable, efficient, and easy to maintain.

9. Radial and axial piston pumps.

10. Centrifugal force and pressure under the vanes hold them out against the ring.

11. The pressure plate seals the cartridge.

12. To vary the outward force from pressure in the high and low pressure quadrants.

13. In variable displacement models of the Inline pump, the swash plate is installed in a movable yoke. The yoke pivots to change the swash plate angle and this increases or decreases the piston stroke.

14. As the cylinder block turns, the piston shoes follow the swash plate, causing the pistons to reciprocate. In a bent-axis pump, the pistons are attached to the drive member so they are forced to reciprocate in the cylinder bore.

15. Although the holding cylinder also has system pressure applied, the area of the stroking cylinder piston is much greater so the force developed moves the yoke up to decrease flow.

Competency:

1. Describe the purpose and operation of accumulators, coolers, heaters, and intensifiers used in a hydraulic system.
2. Identify measurement instruments used in a hydraulic system.
3. Describe the components of a basic hydraulic circuit.
4. Identify the symbols used in a hydraulic circuit.
5. Identify applications of hydraulic circuits.
6. Draw hydraulic circuits.

Instructional Objectives:

1. List functions of an accumulator.
2. Identify types of accumulators.
3. List safety precautions for working with accumulators.
4. Explain reasons for using a cooler.
5. Describe types of coolers.
6. List common failures of coolers.
7. Explain reasons for using a heater.
8. Describe two types of heaters.
9. List two common failures of heaters.
10. Describe the purpose of an intensifier.
11. List three situations where a pressure gauge might be required.
12. Explain how vacuum gauges are calibrated.
13. Identify the components of a basic hydraulic circuit.
14. Distinguish between types of hydraulic circuits.
15. Identify the symbols used in a hydraulic circuit.
16. Identify applications of hydraulic circuits.
17. List the advantages and disadvantages of open-center and closed-center systems.
18. Draw an open-center hydraulic circuit.
19. Show the oil flow in a circuit.

Learning Activities:

1. Read Chapters 12 and 13 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units XI and XII in Hydraulics.
3. Complete the Review Questions at the end of Chapters 12 and 13 in the Industrial Hydraulics Manual.
4. Participate in sessions on a hydraulics trainer as provided by your instructor.
5. Complete Assignment 1, "Draw an Open-Center Hydraulic Circuit."
6. Complete Assignment 2, "Show the Oil Flow in a Circuit."

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit Assignment Sheets 1 and 2.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.

Learning Materials:

1. Industrial Hydraulics Manual. Clawson, Michigan: Vickers Technical Training Center, 1986.
2. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (101116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. A copy of each Assignment Sheet and answers to the review questions is included with this unit.
4. Test questions are included in the Hydraulics text.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Answers to Review Questions - Chapter 12

1. Stores energy, absorbs shock, allows the system to build pressure gradually, maintains pressure.

2. Weight-loaded accumulator. Adding or removing weights.

3. Pressure is a function of the compression of the gas.

4. Dry nitrogen.

5. A metal button is used to prevent extrusion of the bladder.

6. It is a device used to multiply pressure.

7. There is a push rod which bears against a plunger whose position is controlled by hydraulic and spring forces.

8. Adjusting pressure control valves, determining the forces being exerted by a cylinder, and determining the torque of a hydraulic motor.

9. A vacuum gauge is calibrated in inches of mercury.

Answers to Review Questions - Chapter 13

1. It is unloaded when the system pressure exceeds the setting of the unloading valve. The valve opens permitting the large volume pump to discharge to the tank at little or no pressure.

2. The main relief valve.

3. By venting the relief valve and by use of a direct acting unloading valve.

4. By using a deceleration valve or a directional valve.

5. See Figure 13-11.

6. See Figure 13-13.

7. In an open circuit the pump draws its supply from the reservoir. Its output is directed to a hydraulic motor and discharged from the motor back into the reservoir.

   In a closed circuit drive, exhaust oil from the motor is returned directly to the pump inlet.

8. Variable displacement pump and a fixed displacement motor.

Competency:

1. Demonstrate the ability to troubleshoot and maintain hydraulic systems.
2. Demonstrate the ability to diagnose and test hydraulic systems.

Instructional Objectives:

1. Name three reasons for performing preventive maintenance.
2. List four factors that can damage a hydraulic system.
3. Identify key maintenance problems.
4. List steps in keeping the hydraulic system clean.
5. List steps to be performed for general maintenance of a hydraulic system.
6. Demonstrate the ability to perform general maintenance procedures on a hydraulic system.
7. Demonstrate the ability to change hydraulic fluid and filters.
8. Define terms associated with diagnosis and testing.
9. Arrange in order the steps in troubleshooting.
10. Identify the types of hydraulic system testers.
11. List problems and remedies for inoperative systems.
12. List problems and remedies for systems that operate erratically.
13. List problems and remedies for systems that operate slowly.
14. List problems and remedies for systems that operate too fast.
15. List problems and remedies for systems that overheat.
16. List problems and remedies for foaming fluid.
17. List problems and remedies for excessive pump noise.
18. List problems and remedies for leaking pumps.
19. List problems and remedies for load drop when the control valve is in the neutral position.
20. List problems which can cause the control valve to stick or work hard.
21. Identify problems which can cause a control valve to leak.
22. List problems which can cause a cylinder to leak.
23. List problems which can cause a cylinder to actually lower when the control valve is moved to slowly raise a cylinder.
24. Demonstrate the ability to test a hydraulic pump.
25. Demonstrate the ability to locate a problem in a hydraulic system.
26. Demonstrate the ability to test a relief valve.
27. Demonstrate the ability to test a control valve.
28. Demonstrate the ability to test an actuator.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Units XIII and XIV in Hydraulics.
2. Participate in sessions on a hydraulics trainer as provided by your instructor.
3. View the videotape series - Troubleshooting Hydraulics (Tel-A-Train).

Application Exercises:

1. Demonstrate the ability to perform general maintenance procedures on a hydraulic system.
2. Demonstrate the ability to change hydraulic fluid and filters.
3. Demonstrate the ability to test a hydraulic pump.
4. Demonstrate the ability to locate a problem in a hydraulic system.
5. Demonstrate the ability to test a relief valve.
6. Demonstrate the ability to test a control valve.
7. Demonstrate the ability to test an actuator.

Evaluation/Checklist:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture hydraulics trainers are listed in Hydraulics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises are in the Hydraulics text. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Decker, R. Hydraulics. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1986. An instructor's guide (101111), a student manual (101112), and a transparency set (10116) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets and tests.
2. Test questions are included in the Hydraulics text and also questions are available based on the Troubleshooting Hydraulics videotape series.

Audio-Visual Material:

1. The videotape series Troubleshooting Hydraulics is available from Tel-A-Train. This series consists of five videotapes, an instructor's guide, a student text, and a final exam.

   "Troubleshooting Techniques" introduces the troubleshooting of industrial hydraulic systems as a logical process of elimination. Seven basic steps for troubleshooting are introduced, and their importance is demonstrated in common situations.

   "Heat and Leakage" explores two common root causes for hydraulic system failure: heat and leakage. An explanation of the effects of heat and leakage on the entire system is also given, with tips on how these factors can be controlled.

"Contamination" concentrates on the third root cause of hydraulic system failure, contamination. How contaminants are generated within a hydraulic system and external infiltration are covered. Other subjects include preventive maintenance routines and filter monitoring.

"Analyzing Component Faults" demonstrates ways of logically isolating malfunctions in hydraulic components. Pumps, actuators, relief valves, and pilot operated directional control valves are covered.

"Applied Troubleshooting" focuses on troubleshooting hydraulic systems. Realistic problems are demonstrated and solved using basic troubleshooting techniques. A review of the seven basic troubleshooting tips is included.

Resources:

1. A listing of books and audiovisual materials is detailed in Hydraulics I.
2. In the instructor's guide for Hydraulics, suggested supplemental materials are listed for each unit.

Competency:

1. Evaluate different types of insulation that are used in the pipefitting trade.
2. Demonstrate the ability to repair and install insulation.

Instructional Objectives:

1. Define terms that are used in describing insulating material.
2. Explain reasons for insulating.
3. Identify characteristics of insulating materials.
4. Describe different types of insulation.
5. Describe different types of lagging materials.
6. Identify the uses of insulation and lagging materials.
7. Describe the installation procedures for using insulation.
8. Identify insulation requirements when installing insulation materials.
9. List installation procedures in regard to the application and maintenance of insulation.
10. Install/repair insulation on piping in a process steam system.
11. Install/repair insulation on valves and fittings in a process steam system.

Learning Activities:

1. Read Insulation Information Sheet.
2. Read "Foamglas Insulation Systems" from Pittsburgh Corning.
3. Review the tables in Chapter 14 of Pipe Fitting and Piping Handbook.
4. View the videotape "Insulation - Covering Hot Piping" (Marshall Maintenance Production), or the videotape "Thermal Insulation" (NUS Training Corporation).

Application Exercises:

1. Install/repair insulation on piping in a process steam system.
2. Install/repair insulation on valves and fittings in a process steam system.

Evaluation Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. "FOAMGLAS Insulation Systems" is a design/marketing booklet available from: Pittsburgh Corning Corporation, Industrial Insulation Marketing Department, 800 Presque Isle Drive, Pittsburgh PA 15239, (412) 327-6100. Ask for booklet FI-201 20M.
2. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
3. A copy of the information sheet and the test and answers is included with this unit.

Audio-Visual Materials:

1. The videotape "Insulation - Covering Hot Piping" is available from Marshall Maintenance Productions. The tape covers the use of calcium silicate and glass fiber insulation to cover piping. They demonstrate the recommended practices used to cover screwed, welded, and flanged fittings and flanged valves. They demonstrate the use of open weave glass cloth and the application of various finishes for outdoor as well as indoor protection of the insulation.

2. The videotape "Thermal Insulation " is available from NUS Training Corporation. This unit introduces the concept and types of thermal insulation (why it is used, how it works, and how heat is transferred) so trainees can learn to select the right insulation for a particular application. Safety precautions required when dealing with different types of insulation--calcium silicate, fiberglass, rubber, foam, etc.--are stressed. At completion of the unit, trainees will be able to remove and replace insulation under supervision. A workbook is supplied with the unit.

Insulation Information Sheet

You will hear a number of terms used in discussions of topics relating to insulating materials and their uses. Some of the common terms that you should be familiar with are defined below.

THERMAL CONDUCTIVITY is a specific property of a material that relates to the material's heat transmitting characteristics. It is commonly referred to as the material's "K" factor and is the amount of British thermal units per square foot, per hour, per degree Fahrenheit, that can penetrate the material for a thickness of 1 inch. Some of the commonly used insulating materials and their "K" (conductivity) factors are:

Material	"K" Factor
Air (dead)	0.175
Wool, pure	0.26
Cork with pitch	0.428
Sawdust, pine	0.57
Glass	5.0

Materials of low thermal conductivity are of great value in both heating and refrigeration.

CONDUCTION is the flow of heat from one part of a body to another part of the same body, or from one body to another with which it is in physical contact, without displacement of the particles of the body. It takes place from the region of the higher temperature to the region of the lower temperature. This mode of heat flow is most important in insulation. It is the low conduction which results in the greatest temperature differential between a hot insulated surface and the atmosphere, such as in steam piping insulation, or the relatively warm atmosphere and a cold surface, as in refrigerating plant insulation.

CONVECTION is the transfer of heat by the movement of a substance (gas or liquid) through a space. Examples of this include a current of warm air in a room, a current of warm water such as the Gulf Stream, and warm air rising from a hot-water or steam radiator.

RADIATION is a heating process that takes place through air and transparent substances, and does not heat the air through which it passes, but heats only the object upon which it falls. A hot body gives off energy in the form of radiant heat which is emitted in all directions. Radiant heat, like light, travels in straight lines and with the speed of light. The surface conditions greatly affect the ability of a body to radiate heat. Dull, dark, rough-finished surfaces are the best radiators. Conversely, bright, shiny, smooth surfaces are good heat reflectors.

FASTENERS are miscellaneous items used to attach an insulating material to a surface being covered, and to fix lagging to an insulating material.

LAGGING is a protective and confining covering or jacket placed over actual insulating materials.

THERMAL INSULATION is an insulating material used to reduce the transfer of heat from or to a body or surface which is hotter or colder, respectively, than the surrounding atmosphere. Such materials are of low thermal conductivity.

REASONS FOR INSULATING

The primary reason for the application of an insulating material is to form a barrier which will prevent the flow of heat, condensation, and sound.

In almost all utility plants, the loss of heat from heated surfaces and the flow of heat to cooled surfaces are important considerations of efficiency and economy. In addition, the bare heated surfaces of equipment and piping systems are hazardous to personnel; thus, an important safety aspect of insulation is the prevention of injuries due to burns. Also, where convection movements effect heat transfer-such as in refrigerated stores spaces or in household refrigerators-uniform heat distribution (temperature) is facilitated by insulating barriers.

Insulation is often required where the accumulation of moisture by condensation (sweating) forms on the outside of cold pipes and cold air ducts. Both the corrosive condensate that forms and the heat flow resulting in its formation are undesirable.

Sound or acoustical equipment requires insulation with special sound-absorbing characteristics which may be used internally as a duct lining to reduce sound transmission. This insulation may also be used for subduing the noise made by the flow of water inside pipes, such as the flow of water from water closet discharges.

INSULATING MATERIALS

All thermal insulating materials are poor heat conductors. Air conveys heat readily if permitted to circulate, but it is a very poor conductor of heat when held motionless. Insulating materials are manufactured in such a way that air in very small amounts is contained within tiny air cells and is prevented from moving or circulating. An insulating material, to be successful, must be capable not only of preventing the loss of heat, but also of withstanding the effects of vibration and high temperature, and of retaining its insulating qualities throughout a period of years.

The following requirements should be met, as nearly as possible, for thermal insulating materials:

1. Low heat conductivity.
2. Noncombustibility.
3. Light weight.
4. Capability of easy molding and application.
5. Moisture repellent.
6. Noncorrosive, insoluble, and chemically inactive.
7. Composition, structure, and characteristics unchanged by temperatures at which the material will be used.

8. Once installed, should not cluster, become lumpy, disintegrate or build up in masses from vibration.
9. Verminproof.

You will be using insulation products which are manufactured by patented processes, such as Foamglas, Fibrocel, Sprongex, Silvercote, Styrofoam, Fiberglass, and Aircel. When these materials are used, thermal charts and installation instructions obtained from the MANUFACTURER MUST BE USED. Some of the common types of insulating materials which are available are discussed below.

PREFORMED 85-PERCENT MAGNESIA

The material known as 85-percent magnesia is a molded product formed from a combination of 85-percent magnesium carbonate with about 15-percent asbestos fiber for strength and bond. It is made in standard and light density, and weighs 13 pounds per cubic foot. The pipe covering is furnished in cylindrical sections 3 feet long, split in half lengthwise. Larger sizes are furnished in quadrant or segmental form. Sections which become broken may be reused as plastic cement by breaking up the material and mixing it with water. It is suitable for temperatures from 120 to 600 degrees F.

MOLDED CELLULAR GLASS

Molded cellular glass thermal insulation is furnished in three types: blocks, pipe and tubing insulation, and special shapes. This material consists of glass composition which has been foamed or cellulated to create separate hermetically sealed glass cells, each a tiny dead air insulating space. It is noncombustible, rotproof and acidproof. The weight is between 8 to 10 pounds per cubic foot and its temperature application ranges from -50 to 800 degrees F.

FELT INSULATING MATERIALS

Fiber glass materials are ordinarily used for higher temperature insulation, but are also available for special applications at various temperatures.

A thermal fibrous glass felt processed from a molten state into a fibrous and flexible bonded material is available. It is a noncombustible, fire-retardant insulation that has different applications based on densities ranging from 0.65 pounds per cubic foot up to 3 pounds per cubic foot.

Thermal glass fiber insulation felt is composed of staple glass fibers felted into rovings (slightly twisted strands of fibers) and then woven or bound with asbestos thread (which contains a wire insert) to form a flexible blanket. It is used as insulation felt for thermal control of machinery and equipment at temperatures up to 1200 degrees F. The felt is furnished in widths of 60 inches and in rolls 50 feet in length. The thicknesses are 3/4 inch, 1 inch, and 1 1/2 inches. Fibrous glass felt insulation is composed of glass fibers bonded together to form a semi-rigid batt. The fibrous glass is pure glass in fibrous form. It is inorganic, fireproof, and resistant to saltwater and some chemical actions. It cannot mildew, decay, or provide sustenance to insects, rodents, or vermin. Standard dimensions are

48 inches long by 24 inches wide by 1 to 4 inches thick. When this material is used at elevated temperatures, the binding agent burns out at a point between 450 and 600 degrees F. Hence, batts should be enclosed by sheet steel for support when subjected to temperatures between 450 and 900 degrees F.

MISCELLANEOUS INSULATING MATERIALS

Mineral wool blanket insulation consists of fibers from slag, glass or argillaceous limestone made by a process of melting, blowing or drawing, and annealing. The blankets are felted and reinforced by wire netting or metallic lathing on both sides. The material is suitable for use at temperatures up to 900 degrees F.

High temperature insulation cement is available in two types: type A or type B. Type A is the diatomaceaous earth or exfoliated mica type. It is composed of a dry mixture of suitable grades of refractory material ground fine, and clay binders, thoroughly mixed to obtain uniform distribution of the ingredients. Type B is the rock or mineral-wool type which consists of a dry mixture of rock or mineral-wool fibers, and binders, thoroughly mixed to obtain uniform distribution of the ingredients. The composition of the cement is such that when properly wetted with freshwater, it can be applied with a towel or by hand to hot and cold surfaces. One hundred pounds of dry cement will cover 50 square feet of surface to a thickness of 1 inch. After application it weighs a maximum of 30 pounds per cubic foot. The cement is reclaimable. The thermal conductivity of this material is higher than the nonplastic materials. Type B cement can be used to fill all cracks when using block or sectional pipe insulation used on fittings or valves, or over wire netting to smooth the surface.

Cork pipe covering is molded and is composed of cork joined by and coated over with a vapor-sealing compound. The pipe covering sections are made of pure granulated cork compressed into molds and held together by the natural cork gum as a binder. The fire-retardant vapor-sealing compound is composed of chlorinated resins, drying oils, dryers, and fillers. A volatile solvent is added to attain the necessary fluidity for easy application with a stiff brush or trowel. At the time of installation, the untreated molded cork insulating material is coated on all surfaces with the vapor seal. Each delivery of cork should include sufficient copper-clad steel wire and vapor seal for complete application. The molded cork is available in the following types: ice water thickness, brine thickness, and special brine thickness. Pipe covering is furnished in cylindrical sections 3 feet long, split in half lengthwise. This material is of low thermal conductivity and high structural strength, is almost free from shrinkage, resists moisture penetration when thoroughly coated, and acts as a good insulating material for refrigeration service.

LAGGING MATERIALS

Lagging, as explained earlier, is a protective and confining covering or jacket placed over the actual insulating materials. As such, it protects the relatively soft insulating material from mechanical abuse. The lagging also supports the insulating material which is subject to vibration and provides a smooth surface for painting. The following materials are normally used as lagging:

CLOTH: fibrous glass cloth, tape and thread.

BRATTICE CLOTH: fire-resistant cotton cloth used for repairing surfaces of fibrous glass insulation board and as lagging material for thermal insulation, fibrous glass, felt, cork, high temperature insulating cement and mineral wool for pipe temperatures from -20 to 500 degrees F.

PAPER: flameproof and water-repellent sheathing paper.

FIBROUS GLASS CLOTH, TAPE, AND THREAD are manufactured from a good quality of fibrous-glass yarn. The tapes and cloths are made in various weights and weaves. Tight, satin weave, lightweight cloth is recommended for straight pipe. For irregular surfaces, tight, broken-twill weave, heavyweight cloth should be used. Medium, plain weave, lightweight tape in 2, 3, and 4-inch widths is suitable for curved pipe in particular. Tapes are applied with a minimum amount of labor and time. The sewing thread should be of continuous filament yarn. **FIBROUS GLASS MATERIALS ARE NOT RECOMMENDED FOR USE WHERE LAGGING IS EXPOSED TO MECHANICAL INJURY.** The material may be used for lagging surfaces with internal temperatures up to 1050 degrees F, but should not be used on removable and replaceable covers nor where it will be in contact with hot metal surfaces.

SHEATHING PAPER is made in one type. The flameproof and water-repellent paper does not support combustion and absorbs only the specified small weight of water. This material is used in conjunction with other lagging. It is supplied in rolls 36 inches wide.

INSULATION PRACTICES

The selection of insulation material will vary, depending on the require- of the individual system. Exterior piping installed above frost level and interior piping (including drainage traps) subject to freezing should be **FROSTPROOFED**. Where piping is subject to sweating, provide **SWEATPROOFING**.

Damage and interruptions of service may result where pipes are subject to freezing. Therefore, it is essential that freeze protection be provided. Insulation alone cannot prevent the freezing of water where the water remains still and the temperature of the surrounding air remains sufficiently low. Insulation will, however, prolong the time required for the water to give up its heat and the temperature of the water to be lowered to the freezing point. The rate at which still water may freeze will depend upon such factors as the initial water temperature of the surrounding air, air velocity, and the amount of water present (in the case of water within a pipe, the pipe size.) For some examples, water in a 1/2-inch pipe with an initial temperature of 42 degrees F, protected by 2 inches in thickness of insulation (K = 0.30) surrounded by -18 degrees F air, would freeze in less than 1/2 hour. Water in a 2-inch pipe under the same conditions would freeze in about 2 hours. If the thickness of the insulation for the 2-inch pipe is increased to 4 inches, it would take about 3 hours for the water to freeze. If the initial water temperature is increased from 42 to 52 degrees F (temperature above freezing point doubled), the time lapse required for freezing will be prolonged to twice what it was at 42 degrees F. Where insulation is installed the velocity of air will have little effect and need not be taken under consideration. The amount of insulation required to prevent sweating will be the thickness required to prevent the outer surface temperature of the insulation material to cool below the dew point. This temperature may be determined by the use of a psychrometric chart.

Heating Systems

Thermal insulating materials have the property of resisting the flow of heat. This property is used in heat distribution systems for the following purposes:

1. To prevent heat loss.
2. To prevent condensation of steam in steam lines.
3. To maintain desired fluid temperatures.
4. To protect personnel from high temperatures, as in manholes and pits.

For proper selection of insulation material to be used in steam distribution systems, use tables in Pipe Fitting and Piping Handbook, Chap. 14, as a guide.

Aboveground piping is covered with insulation and then furnished with a protective covering of one layer of impregnated roof felt and an aluminum jacket. This covering provides protection against weather and mechanical damage. The felt is applied with longitudinal and circumferential seams lapped not less than 4 inches and secured with stainless steel staples. The aluminum jackets, longitudinally corrugated for strength, should be not less than 0.017 inch thick, and the longitudinal and circumferential seams should be lapped not less than 2 inches. Jackets are secured with aluminum strips or with stainless steel sheet metal screws set on not more than 5-inch centers on the longitudinal and circumferential seams. Indoor insulation may be protected to a certain extent by wrapping it with canvas, and then painting the canvas. Metal protective coverings should be provided where necessary to protect the insulation from damage.

In steam distribution systems that use ferrous condensate return lines, it is customary to provide a separate conduit for the insulated condensate return piping. This is done because the return piping is more subject to corrosion which makes its life considerably shorter than the life of the steam pipes. When nonferrous condensate return lines are used, they are enclosed with steam lines in the same conduit. Condensate return piping installed in the same conduit with the steam piping need not be insulated. However, condensate return piping in manholes should be insulated with insulation of the same material and thickness required for steam piping of the same size.

Underground distribution systems are employed for permanent installation where local conditions require their use. They are more costly to install and more difficult to maintain than aboveground systems. Underground distribution systems consist of conduits of several types, sizes and shapes which contain the distribution piping. These conduits provide an enclosure which affords mechanical protection as well as a waterproof cover for the insulating material of the pipes. Pipe insulation should be a nonconductor of electricity, verminproof, rot resistant, and noncorrosive to the pipe when wet. All piping, flanges, valves, field joints, and fittings should be insulated with the same material and equal thickness as the insulation of the adjoining pipe. A continuous annular space is commonly provided between the outer surface of premolded or preformed pipe insulation and the inner surface of the exterior casing. This provides adequate continuous air space for venting and draining.

Smokepipes, flues, or hot air ducts that pass through the partitions, floors, ceilings, or roofs of a building should be protected by fire-retardant thermal insulation or suitable airspaces around the heated passages. The insulation should be amply thick for the temperature, secured firmly, and extend far enough along the hot surfaces to minimize the fire hazard.

INSTALLING INSULATION

Insulating materials must be capable of withstanding the effects of vibrations and high temperatures as well as preventing the flow of heat. The applicable procedures and precautions that are necessary for different insulating jobs determine to a great degree the life and effectiveness of the materials used.

INSTALLATION PROCEDURES

A brief discussion of the installation procedures applicable to piping systems and valves, fittings and accessories follows.

Piping Systems

There are three major steps in covering pipe. First, there is the application of the insulation, usually a molded pipe covering. Then the joints between the sections of this covering must be filled in with insulating cement. The third step involves the application of an outside covering (lagging) such as fibrous glass cloth or, in some cases, canvas.

Molded pipe covering is intended for use on straight pipe. It can usually be applied to a large radius bend by pressing the material against the pipe. For most bends, however, the material will be too brittle to conform. Just as you have to lay off a bend area into segments in order to make a smooth bend, you will have to cut the insulating material in wedges. The sharper the bend, the smaller the wedges should be. If any wedges fail to fit on the bend being covered, do not throw them away; most likely you can use them later for other jobs that will be coming up. In applying the blocks of covering material, rotate them around the pipe to check for tightness of fit. In wiring them together, make turns in the wire by hand, and then use pliers to tighten them. Take up slack (about a quarter turn away from the twisted ends of the wire) by making a single kink.

Always start applying the pipe covering at a fitting, coupling, or hanger, and stop at one. You can see that it is not a good idea to carry the covering over fittings, since the outside diameter of a fitting is larger than that of the pipe. Unions joining pipe that is 2 inches, iron pipe size (IPS), or less are usually not covered, since heat loss is negligible. A good rule is to do the line first, and then go back to do the fittings. Install the inner layer first. When installing the outer layer, stagger the joints to avoid having them line up with those of the inner layer.

In covering bends, allow for more clearance between the seam faces of the insulation blocks than you allow on straight runs, and use at least two wire bends to fasten each wedge. Let the seams lie along the throat and the heel of the bend, not along the side of the pipe as in straight pipe covering.

Insulating cement is generally used to seal cavities in the molded pipe covering; when heavy layers must be applied over large areas, it is desirable to add strength to the cement coating by using wire mesh.

Insulating cement is furnished in dry form and must be mixed with water to form a mixture of the right consistency. Your biggest problem with these mixtures will probably be that of getting the proper consistency. Use a sloppy mixture when you have to spatter the cement on hot fittings or other hot metal surfaces. Use a very stiff mixture for filling deep cavities or any depression where the surface will not absorb moisture. Use a consistency somewhere between these two when you are applying the cement to ordinary seams, joints, or defects.

Lagging cloth or tape may be applied with an adhesive material or it may be installed by sewing it in place. The adhesive material must be an approved type for the particular lagging material. When sewing lagging in place, a certain amount of skill is necessary. A protective device known as a leather palm should be used.

Insulation for pipe in a system that operates with a surface temperature in the range of 125 to 1050 degrees F should consist of compounded or fibrous material of magnesia, calcium silicate, and/or diatomaceous earth, suitable for the respective temperature ranges. The insulation should be applied directly to the pipe, either in a single or double layer, and should be held in place with at least three fastenings to every 3-foot section. These fastenings may be flat bends or they may be 18-gauge annealed iron wire, black or hot-dipped galvanized.

The lagging installed over this insulation should be of cloth or tape, and the material itself should be fibrous glass, or brattice cloth, suitable for the specific temperature range. The lagging may be applied by sewing with thread that is similar to the lagging material, or by the use of a silicate adhesive.

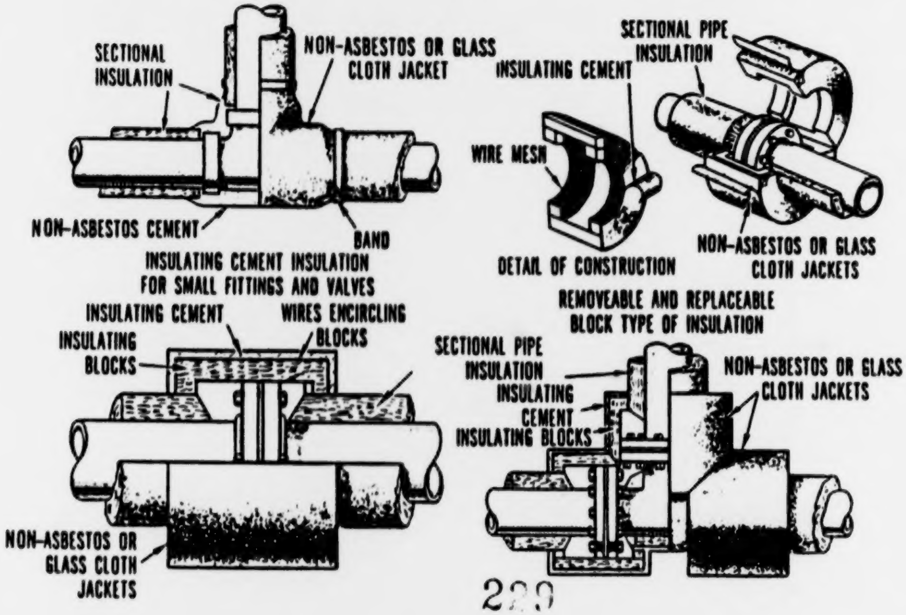
Antisweat insulation materials should consist of molded thermal material or fibrous glass felt. The insulation should be installed by tightly wrapping the surface with a layer of sheathing paper that is water-repellent and flameproof. Secure this paper with cotton twine, or with a 1-inch wide tape. Lap the joints and then seal them with adhesive cement. Compatible lagging is then installed and completely covered with a vapor barrier compound.

Refrigerant insulation may be of cork or cellular glass. When molded cork insulation is used, it should be coated on all surfaces with a vapor barrier compound. Secure the insulation with loops of 18-gauge copper-covered steel wire, spaced so that there will be not more than six such loops to each 3-foot section. When cellular glass insulation is used, it must be coated with a vapor barrier coating on the butt ends, the bore, and the longitudinal joint surfaces. The outside surface of this insulation should be lightly coated, just enough to fill the surface cells; the coating should not be more than 1/16 inch thick. Install this cellular glass insulation in sections, with staggered joints, and with one-half of a section extending beyond the opposite end joint. Then secure the sections with 22-gauge galvanized steel bands on 9-inch centers.

Suitable lagging material for use with molded cork or cellular glass insulation consists of fire-resistant cotton brattice cloth or fibrous glass cloth or tape.

Valves, Fittings, and Accessories
Any one of the following methods of fabrication is acceptable for piping components.

1. Covers may be made in two halves out of thermal insulating felt enclosed with 0.008-inch diameter knitted wire mesh on the inside and end surfaces. The outside of the covers have a fibrous glass fabric. Each half cover may be sewn and quilted with polytetrafluoroethylene (PTFE) coated fibrous glass yarn or thread. The covers may also be fastened with stainless steel staples to provide uniform thickness, strength, and rigidity.


SECTIONAL INSULATION
NON-ASBESTOS OR GLASS CLOTH JACKET
NON-ASBESTOS CEMENT
BAND
INSULATING CEMENT INSULATION FOR SMALL FITTINGS AND VALVES
SECTIONAL PIPE INSULATION
INSULATING CEMENT
WIRE MESH
DETAIL OF CONSTRUCTION
NON-ASBESTOS OR GLASS CLOTH JACKETS
REMOVEABLE AND REPLACEABLE BLOCK TYPE OF INSULATION
INSULATING CEMENT
WIRES ENCIRCLING BLOCKS
INSULATING BLOCKS
NON-ASBESTOS OR GLASS CLOTH JACKETS
SECTIONAL PIPE INSULATION
INSULATING CEMENT
INSULATING BLOCKS
NON-ASBESTOS OR GLASS CLOTH JACKETS

—Permanent-type insulation of pipe fittings, flanges, and valves.

2. Covers exposed to temperatures of 450 degrees F and above have a 0.008 inch diameter knitted wire mesh on the inside surface and on the ends. Fibrous glass cloth is used on all outside surfaces. Covers for use at temperatures of 850 degrees F and above have a filling consisting of fibrous glass felt. The knitted wire mesh is made of 304 annealed stainless steel.

INSTALLATION PRECAUTIONS

Observe the following general precautions when you apply and maintain insulation:

1. Fill and seal all air pockets and cracks. Failure to do this will cause large losses by conduction and by convection currents.
2. Seal the ends of the insulation and taper off to a smooth, airtight joint. Use sheet metal lagging at joint ends or other points where insulation is liable to damage. Cuff flanges and joints with 6-inch lagging.
3. Fibrous glass cloth covering fitted over insulation should be tight and smooth. It may be sewed with yarn or may be cemented on.
4. Keep moisture out of all insulation work. Moisture is an enemy of heat insulation. Any dampness increases the conductivity of all heat-insulating materials.
5. Insulate all hangers and other supports at their point of contact from the pipe or other unit they are supporting. Otherwise a considerable quantity of heat will be lost through the support via conduction.
6. Sheet metal covering should be kept bright and not painted unless the protecting surface has been damaged or has worn off. The radiation from bright-bodied and light-colored objects is considerably less than from rough and dark-colored objects.
7. Once installed, heat insulation requires careful inspection, upkeep, and repair. When you remove lagging and insulation to make repairs, it should be replaced just as carefully as when originally installed. When replacing insulation, make certain that the replacement material is the same as the original. Old magnesia blocks and sections broken in removal can be mixed with water and reused in the plastic form for temporary repairs.
8. Insulate all flanges with easily removable forms which can be made up as pads of insulating material wired or bound in place. Cover the whole thing with sheet-metal casings which are in halves, and easily removable.

   Lag the main steam, auxiliary steam, auxiliary exhaust, feed water, and steam heating piping systems to hold in the heat. Lag the circulating drainage, fire, and sanitary piping systems to prevent condensation of moisture on the outside of the piping.

REFERENCES:

1. Hull Maintenance Technician 3 & 2, Vol. 1, (NAVEDTRA 10571). Washington, D.C.: U.S. Government Printing Office, 1984. (Stock Ordering No. 0502-LP-052-8630)
2. Utilitiesman 1 & C, (NAVTRA 10657-F). Washington, D.C.: U.S. Government Printing Office, 1981. (Stock Ordering No. 0502-LP-053-2865)

Insulation Test

_____1. The thermal conductivity ("K" factor) of a solid expresses the

a. quantity of heat flow through the solid during a given period of time
b. quantity of heat the solid is capable of absorbing
c. temperature of the solid during any period of time
d. differences in temperature between the surfaces of the solid

_____2. The transfer of heat by the movement of a gas or liquid through a space is known as

a. conduction
b. convection
c. radiation

_____3. Which of the following materials has the best thermal conductivity characteristics for use as insulation?

a. Dead air
b. Wood
c. Glass
d. Copper

_____4. Which of the following objects, surrounded by air, will radiate heat most effectively?

a. A rough finished piece of cast iron
b. A rough finished piece of tinfoil
c. A piece of highly polished metal
d. A mirror

_____5. If you hold a piece of ice in your hand, by what mode does heat transfer from your hand to the ice?

a. Radiation
b. Convection
c. Reflection
d. Conduction

_____6. After installation, insulating materials are generally protected from the surrounding environment by

a. lagging materials
b. wire fasteners
c. dull radiators
d. air convectors

_____7. Condensation on air-conditioning ducts should be prevented because it causes which of the following?

a. Polluted air
b. Clogged filters
c. Electrolysis
d. Corrosion

_____8. Why is thermal insulating material a good heat resistor?

a. Because it is a solid
b. Because it contains numerous tiny cells filled with motionless air
c. Because it permits air to flow freely.around the part it insulates
d. Because its construction is a mass of tiny vacuum cells

_____9. Of the following, which is an important characteristic of a good insulating material?

a. High heat conductivity
b. Ability to withstand high temperatures
c. Chemical activity
d. Ability to absorb moisture

_____10. Which of the following types of insulating material can be broken up and mixed with water to form a plastic insulating cement?

a. Preformed fibrous asbestos
b. Molded cellular glass
c. Asbestos fiber
d. Preformed 85-percent magnesia

_____11. Which of the following types of insulating material is best suited for the thermal control of equipment that is subjected to temperatures of up to 1200 degrees F?

a. Fibrous glass felt insulation
b. Thermal glass fiber insulation felt
c. Molded cellular glass thermal insulation
d. Mineral wool blanket insulation

_____12. Which of the following types of insulating material should be enclosed by sheet steel when subjected to temperatures between 450 and 900 degrees F?

a. Thermal glass fiber insulation felt
b. Mineral wool blanket insulation
c. Fibrous glass felt insulation
d. Asbestos insulating felt

_____13. How much high-temperature insulation cement will you need to insulate 125 square feet of surface, if you apply a thickness of 1 inch?

a. 100 lb.
b. 200 lb.
c. 250 lb.
d. 300 lb.

_____14. Lagging is used on insulation to

a. protect the insulation
b. provide additional insulation
c. waterproof the insulation.
d. form a moisture barrier

_____15. Which of the following factors should you take into consideration when determining the thickness of insulation for freeze protection of water piping?

a. Initial water temperature
b. Pipe size
c. Temperature of the surrounding air
d. Each of the above

_____16. The thickness of insulation which will prevent sweating on the surface of cold waterlines is an amount that will prevent the outer surface temperature of the insulating material from cooling below the

a. ambient temperature
b. dew point
c. freezing point
d. sensible temperature

_____17. What thickness of insulation having a "K" factor of 0.25 is required for a 4-inch steam distribution line?

a. .75 in.
b. 1.0 in.
c. 1.5 in.
d. 2.0 in.

_____18. The longitudinal and circumferential seams of the impregnated roof felt used to cover the insulation of aboveground steam piping should be lapped at LEAST

a. 5 in.
b. 2 in.
c. 3 in.
d. 4 in.

_____19. If you do not have aluminum strips to secure the aluminum jackets covering piping insulation, you should secure the jackets with

a. stainless steel sheet metal screws set on 10-inch centers
b. stainless steel sheet metal screws set on maximum 5-inch centers
c. thermal insulating tape
d. high-temperature insulation cement

_____20. Insulation is NOT required on which of the following condensate return lines?

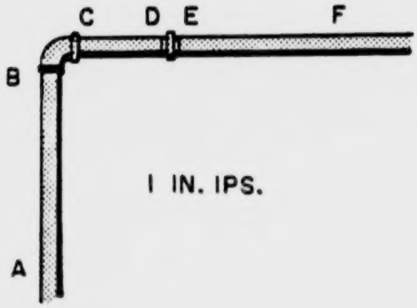
a. Ferrous condensate return lines
b. Nonferrous condensate return lines enclosed in conduits separate from the steam lines
c. Nonferous condensate return lines in the same conduit with the steam lines
d. Ferrous and nonferrous condensate return lines in manholes

_____21. The third step in installing preformed insulation on pipe involves the application of

a. paint
b. cement
c. tape
d. lagging

_____22. How should you install molded pipe insulation to sharp bends?

a. By cutting the insulating material into wedges and fitting them around the bend
b. By preworking the material until it becomes soft and then molding it around the bend
c. By gently pressing it against the pipe until it conforms to the bend
d. By breaking the material into small irregular pieces and applying it with high-temperature insulating cement



_____23. A correct way to insulate the pipe in the above figure with molded pipe covering insulation is to cover from

a. a to f continuously
b. f to a continuously
c. c to d, e to f, and b to a
d. b to a and c to b

_____24. When you are covering pipe bends, the seams of the covering material should lie

a. along the side of the pipe
b. along the heel and throat of the bend
c. on the top and the bottom of the pipe
d. at a 45 degree angle to the heel and throat of the bend

_____25. Which type of insulating cement mixture should be prepared for use in filling deep cavities in molded pipe covering?

a. Stiff
b. Low slump
c. Sloppy
d. Somewhere between stiff and sloppy

_____26. How many fastenings are required to hold two 3-foot sections of insulation to a hot pipe?

a. 6
b. 9
c. 3
d. 12

_____27. When you are installing antisweat insulation materials, the final step of the procedure is to

a. secure the sheathing paper with twine
b. paint the surface with waterproof paint
c. cover the lagging with a vapor barrier compound
d. seal the joints with adhesive cement

_____28. Cellular glass insulation should be secured to refrigeration piping with

a. 22-gage galvanized iron straps on 12-inch centers
b. 18-gage copper-covered steel wires on 6-inch centers
c. 22-gage galvanized steel bands on 9-inch centers
d. 18-inch annealed iron wire on 3-foot centers

_____29. When installing insulating felts to a system operating above 850 degrees F, you must use certain materials and apply them in a particular order. Which of the following lists names the material in their order of application?

a. Fiber glass felt, iron netting, insulating cement, finishing cement, lagging
b. Insulating cement, fiber glass felt, finishing cement, lagging
c. Vapor barrier compound, fiber glass felt, finishing cement, water repellent sheathing paper
d. Magnesia asbestos, iron netting, insulating cement, fiber glass felt, lagging

Insulation Test Answers

1. a
2. b
3. a
4. a
5. d
6. a
7. d
8. b
9. b
10. d
11. a
12. c
13. c
14. a
15. d
16. b
17. c
18. d
19. b
20. c
21. d
22. a
23. c
24. b
25. a
26. a
27. c
28. c
29. a

Basic Mathematics Pretest

Unit 1 - Addition and Subtraction of Whole Numbers

a. 302 431 + 58 ---	b. 12,031 1,224 8,341 + 489 -----	c. 856 322 87 + 75 ---	d. 2,564 8,321 5,763 + 24 -----
e. 926 -336 ---	f. 13,104 - 785 ------	g. 7,086 - 254 -----	h. 25,620 - 8,205 ------

Unit 2 - Multiplication and Division of Whole Numbers

a. 37 x 8 --	b. 40 x29 --	c. 789 x 46 ---	d. 8,240 x 833 ----
e. 224 / 8	f. 3,321 / 27	g. 44,0118 / 326	h. 856 / 9

Unit 3 - Addition and Subtraction of Fractions

a. 3 1 3/64 5/8 + 17/32 -----	b. 12 7/8 + 5 1/6 ------	c. 7/8 11/16 25/32 +59/64 -----	d. 3/4 1/8 3/16 +1/4 ---
e. 16 7/10 -12 2/9 -------	f. 34 1/10 -12 4/15 -------	g. 11' 3 9/6" - 9 4 11/16" -----------	h. 9' 2 3/22" -2' 4 3/4" ---------

Unit 4 - Multiplication and Division of Fractions

a. 5/21 x 3/35

b. 8 1/6 x 4 2/7

c. 48 x 3 3/4

d. 3/4 x 4/9 x 6/7

e. 3 9/16 / 5/32

f. 6 1/8 / 1 3/4

g. 3 3/4 / 1 1/4

h. 27/32 / 3/4

Unit 5 - Addition, Subtraction, Multiplication and Division of Decimals

a. 24 + 3.5 + .28

b. 136.2 + 4.362 + 1.4 + .054

c. .00826 - .001931

d. 1.756 - .825

e. .491 x 29.92

f. .0361 x 82.65

g. 65 x .433

h. 2.31 x .67

i. 1 / .433

j. .675 / .375

k. 62.4 / 7.48

l. .075 / .0361

Unit 6 - Decimal Conversion

Convert decimals to fractions

a. .325   b. .765   To the nearest 32nd

c. .9465   d. .086   To the nearest 64th

Convert fractions to decimals

e. 5/64   f. 7/32

g. 7/8   h. 11/16

Convert decimals of a foot to feet and inches and convert fractions of an inch to the nearest sixteenth of an inch.

i. 3.625'   j. 1.367'

k. 1.065'   l. 2.365'

Subtract and convert the decimals of a foot to inches and fractions of an inch to the nearest sixteenth of an inch.

```
m.  33.397'          n.  21.786'
   -27.654'             -12.479'
    ------               ------


o.   7.566'          p.  .643'
    -3.842'             -.076'
     -----                ---
```

Basic Mathematics Pretest Answers

Unit 1

a. 791
b. 22,085
c. 1,340
d. 16,672
e. 590
f. 12,319
g. 6,832
h. 17,415

Unit 2

a. 296
b. 1,160
c. 36,294
d. 6,863,920
e. 28
f. 123
g. 1,350.05
h. 95.11

Unit 3

a. 5 13/64
b. 18 1/24
c. 3 17/64
d. 1 5/16
e. 4 43/90
f. 21 5/6
g. 1' 10 14/16"
h. 6' 9 11/32"

Unit 4

a. 1/49
b. 35
c. 180
d. 2/7
e. 22 4/5
f. 3 1/2
g. 3
h. 1 1/8

Unit 5

a. 27.78
b. 142.016
c. .006329
d. .931
e. 14.690
f. 2.985
g. 28.145
h. 1.5477
i. 2.309
j. 1.8
k. 8.34
l. 2.077

Unit 6

a. 10/32
b. 24/32
c. 61/64
d. 6/64
e. .078
f. .218
g. .875
h. .687
i. 3' 7 1/2"
j. 1' 4 6/16"
k. 1' 3/4"
l. 2' 4 6/16"
m. 5' 8 15/16"
n. 9' 3 11/16"
o. 3' 8 11/16"
p. 6 13/16"

Competency:
Perform calculations in basic arithmetic.

Instructional Objectives:
1. Add, subtract, multiply, and divide whole numbers.
2. Identify fraction types and convert improper fractions to proper fractions in their lowest terms.
3. Identify common denominators in fractions.
4. Add, subtract, multiply, and divide fractions.
5. Add, subtract, multiply, and divide decimals.
6. Change decimals to fractions.
7. Change fractions to decimals.
8. Convert inches to decimals of a foot.
9. Convert decimals of a foot to inches.

Learning Activities:
1. Complete the Basic Mathematics Pretest. For a score of 90% or better, skip to Math II. For a score under 90%, complete Math I.
2. Read Units 1-12 in Basic Industrial Mathematics.
3. Complete all the Assignments in Units 1-12.

Evaluation/Checkout:
1. Submit the Assignments from Units 1-12.
2. Demonstrate your knowledge of the objectives by completing a test .

Learning Materials:
1. Basic Industrial Mathematics: A Text Workbook. New York: McGraw-Hill Book Company, 1972.
2. An answer key is available for the text from the publisher. Call (800) 334-7344. Ask for 07-017661-2.
3. A copy of the test and answers is included with this unit.

Resources:
1. Audio-Visual Materials:
    A. "Industrial Technologies - Math Review I and II" from L & K International Videotraining. The tape covers addition, subtraction multiplication, division, averages, fractions, decimals, and percentages. The tape is accompanied by a student workbook and an instructor's guide. Purchasers of the program may reproduce the printed material for their own use.

    B. "Plant Mathematics 1 - Principles" from NUS Training Corporation. The four units in this topic teach number structures and the use of conversion factors to enable students to add, subtract, multiply, and divide whole numbers, decimals, and fractions, as well as to convert numbers from one form to another with an understanding of the concept of equality. Positive and negative numbers and simple algebra essential in solving plant-related problems are introduced. Also covered are manipulations involving squares and square roots, percentages, power, and roots. A workbook is supplied with each unit.

Math I Test

1. Change to a mixed number: 30/7

2. Change to a mixed number: 32/7

3. Change to improper fractions:
   a. 2 7/8
   b. 3 1/5

4. Reduce to the lowest terms:
   a. 58/64
   b. 4/32
   c. 152/6

5. State answers to the following equations in the lowest terms possible:
   a. 1/2 + 1 3/4 =
   b. 10 15/16 + 8 9/16 =
   c. 3 5/32 + 2 5/8 + 1 5/64 =
   d. 8 - 3 1/16 =
   e. 175 2/3 - 168 =
   f. 5/16 x 1/8 =
   g. 6 5/8 x 3 =
   h. 13/16 / 1/2 =
   i. 2 1/2 / 3 3/4 =
   j. 3/8 / 1/2 =
   k. 2 3/4 / 5 =
   l. 1 7/8 / 2 1/2 =
   m. 4 / 3/16 =

6. Nine guide pins are to be cut from a 96-inch drill rod. Each pin is 8 inches long. Allowing 3/16 inch waste for each cut, determine the remaining stock.

7. Write .4010 as a common fraction.

8. Write twenty six point two eight six as a decimal.

9. 23.0562 + 8.920 + 33.256 =

10. Write 45 8/10 as a decimal.

11. Write six and forty-one hundredths as a decimal.

12. 706.389 - 35.827 =

13. 8.4 x 7.6 =

14. 6.80 x 13 =

15. 92.686 x 100 =

16. Round to three significant digits: 37.25 - 12.2 =

17. Round to one digit: .397 - 1.63 =

18. Round to two significant digits: .397 - 1.63 =

19. Change 2 3/8 to a decimal.

20. Change 1/5 to a decimal and round to two places.

21. Add 25.86, 96.88, and 3.52.

22. Round to three places: 0.896371.

23. 1079.490 - 880.513 =

24. 1.37 x 100 =

Math I Test Answers

1. 4 2/7

2. 4 4/7

3. a. 23/8
   b. 16/5

4. a. 29/32
   b. 1/8
   c. 25 1/3

5. a. 2 1/4
   b. 18 7/8
   c. 6 55/64
   d. 4 15/16
   e. 7 2/3
   f. 5/128
   g. 19 7/8
   h. 13/64
   i. 9 3/8
   j. 3/4
   k. 11/20
   l. 3/8
   m. 21 1/3

6. 22 5/16

7. 401/1000

8. 26.286

9. 65.2322

10. 45.8

11. 6.41

12. 670.562

13. 63.84

14. 88.4

15. 9268.6

16. 3.053

17. .2

18. 21.163

19. 2.375

20. .20

21. 126.26

22. .896

23. 198.977

24. 137

Competency:
Perform calculations in basic geometry.

Instructional Objectives:
1. Measure the distance between points.
2. Calculate the circumference of a circle.
3. Calculate the perimeters of squares, rectangles, and triangles.
4. Calculate the surface area of squares, rectangles, triangles, and circles.
5. Compute squares and square roots.
6. Calculate the volumes of cubes, rectangles, and cylinders.

Learning Activities:
1. Read Units 17-23 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 17-23.

Evaluation/Checkout:
1. Submit the Assignments from Units 17-23.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:
1. Basic Industrial Mathematics: A Text Workbook. New York: McGraw-Hill Book Company, 1972.
2. An answer key is available for the text from the publisher. Call (800) 334-7344. Ask for 07-017661-2.
3. A copy of the test and answers is included with this unit.

Math II Test

Match the terms at the right with the identifying characteristics on the left.

1. _____ Equilateral
2. _____ Isosceles
3. _____ Obtuse
4. _____ Acute
5. _____ Vertex
6. _____ 180 Degrees

A. The total of all angles in a triangle.
B. Is greater than 90 degrees.
C. Is less than 90 degrees.
D. A point at which two straight lines intersect.
E. A triangle with 3 equal sides.
F. A triangle with 2 sides and 2 angles equal.

7. You are purchasing a fruit tree from a nursery. The tree is priced at $25.00 per inch of diameter. You wrap a tape measure around the tree and find its circumference to be 4 3/4 inches. The tree will cost approximately:

   a. $38.00
   b. $50.00
   c. $29.00

8. You have 80 feet of fence. You figure you can enclose an area of 400 square feet with it. Draw a sketch of the fenced in area giving the length of all sides.

9. Find the area of a circle 16" in diameter.

10. Find the area of a right triangle with a base of 5 feet long and an altitude of 6 feet long.

11. You are ordering concrete for a garage floor 24 feet x 24 feet, 4 inches thick. How many cubic yards are required?

12. A water tower is 40 feet in diameter and 100 feet tall. One cubic foot holds 7.48 gallons. How many gallons of water will the tower hold?

13. L x W x H / 2 = the area of a:

    a. Wedge
    b. Cylinder
    c. Sphere

14. If two angles of a triangle are equal, then the sides opposite them are equal.

    a. True
    b. False

Math II Test Answers

1. E
2. F
3. B
4. C
5. D
6. A
7. A
8. The figure is a square, 20 feet on all sides.
9. 200.96
10. 15 feet
11. 7.104
12. 939,488 gallons
13. A
14. A

Competency:
Perform calculations in basic algebra.

Instructional Objectives:
1. Solve equations by addition or subtraction.
2. Solve equations by multiplication or division.
3. Solve problems dealing with ratios.
4. Set up equations to solve proportions.
5. Solve percentage problems.

Learning Activities:
1. Read Units 13-16 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 13-16.

Evaluation/Checkout:
1. Submit the Assignments from Units 13-16.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:
1. Basic Industrial Mathematics: A Text Workbook. New York: McGraw Hill Book Company, 1972.
2. An answer key is available for the text from the publisher. Call (800) 334-7344. Ask for 07-017661-2.
3. A copy of the test and answers is included with this unit.

Resources:
1. Audio-Visual Materials:
    A. "Industrial Technologies - Math Review III" from L & K International Videotraining. The tape covers algebra, the equation and symbols. The tape is accompanied by a student workbook and the instructor's guide. Purchasers of the program may reproduce the printed material for their own use.

    B. "Plant Mathematics 2 - Principles" from NUS Training Corporation. This topic shows trainees how to solve problems using formulas to calculate plant heat rate, plant performance, percent efficiency, flow rate versus capacity, power factor, deviation from setpoint, and Ohm's Law for series and parallel circuits. In addition, manipulating formulas in order to study the physical laws of nature as expressed in mathematical terms is explained. Included in the problem-solving exercises are: total head calculations using friction head, static head, and velocity head; conversions from Fahrenheit to Celsius, Fahrenheit to Rankine, and Celsius to Kelvin; Boyle's Gas Laws; absolute pressure to gauge pressure conversions; the effect of changes in weight and velocity on kinetic energy;

mass flow measurements using an orifice and a square root extractor; and transformer power laws. A workbook is supplied with each unit.

C. "Industrial Math - 1" from NUS Training Corporation. Industrial Math - 1, first of a two-unit series, reviews concepts of basic math and algebra and covers common industrial measurement units, such as those used for pressure, flow, velocity, concentration, and volume. It also shows how calculators can be used to solve industrial math problems. A workbook is included with each unit.

Math III Test

1. Solve the following problems for the unknown and reduce to the lowest terms.

   a. $8/9 = 3Y/4$

   b. $22a = 42$

   c. $x/37 = 5$

   d. $4/5b - 100/20$

   e. $x/15 = 5/3$

2. Two gears are in mesh, one rotates at 80 rpm, and the other rotates at 15 rpm. What is the rpm ratio?

3. A building is 24' x 36', another building is 20' wide. They both equal the same square footage. What is the length of the second building?

4. A 6' x 9' oil tank holds 864 gallons at the 2' level. How many gallons does it hold when filled to the 3.5' level?

5. A kitchen floor measures 217 feet squared. Figure 25% for waste. How long of a piece of material 12 feet wide is required?

6. A batch of hand lotion is 1000 gallons total. If the mix requires 2% lanolin, how many gallons of lanolin should be used?

7. If a loading ramp is 18 feet long and has a rise of 3 feet, what is the rise on a ramp 11 feet long, assuming all other proportions are the same?

8. Two roofs have equal pitches. One roof has a rise of 4' and a run of 12', the second roof has a run of 19', what is the rise?

9. A bearing weighs 5 lbs. and contains 4 lbs. of lead.
Keeping the proper percentage of lead, how much would a bearing weigh containing 3 lbs. of lead?

Math III Test Answers

1. a. 1.185 or 1 5/27
   b. 1.909
   c. 185
   d. .16
   e. 9.375

2. 5.33 to 1

3. 43.2

4. 1512 gallons

5. 22.6

6. 20

7. 1.83

8. 6.33

9. 3.75

Competency:

1. Perform calculations using right triangles.
2. Perform calculations in trigonometry and generalize their solutions to the trade.

Instructional Objectives:

1. Apply the terminology that is used to name the sides and angles in triangle problems.
2. Calculate the missing angles in triangles when two angles are known.
3. Solve for missing sides of right triangles using the Pythagorean Theorem.
4. Use ratios to understand the relationships between sides of triangles.
5. Identify the six trigonometric functions.
6. Use trigonometric tables to calculate the values for different angles.
7. Use trigonometric tables to calculate the angles to the nearest minute for different values.
8. Use trigonometry to find the missing sides of right triangles.
9. Use trigonometry to find the missing angles of right triangles.
10. Solve piping problems using trigonometry.

Learning Activities:

1. Read Units 24-29 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 24-29.
3. Complete Worksheets 1-7.

Evaluation/Checkout:

1. Submit the Assignments from Units 24-29.
2. Submit Worksheets 1-7.
3. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. Basic Industrial Mathematics: A Text Workbook. New York: McGraw-Hill Book Company, 1972.
2. An answer key is available for the text from the publisher. Call (800) 334-7344. Ask for 07-017661-2.
3. A copy of the test and answers is included with this unit.

Resources:

1. Audio-Visual Materials:
   - A. "Industrial Math - 2" from NUS Training Corporation. Industrial Math - 2 builds on the mathematical concepts presented in Industrial Math - 1 with specific examples of solving process problems using math principles. Emphasis is on reading process indications and using basic math steps to solve process-related problems. A workbook is supplied with each unit.

Math IV - Worksheet 1

Find the natural values for the following angles using the trigonometry tables.

1. Sin 36 degrees 42' = ______________________

2. Cos 40 degrees 20' = ______________________

3. Tan 18 degrees 6' = ______________________

4. Sec 58 degrees 4' = ______________________

5. Csc 42 degrees 8' = ______________________

6. Cot 84 degrees 49' = ______________________

7. Sin 8 degrees 42' = ______________________

8. Cos 41 degrees 18' = ______________________

9. Sec 18 degrees 0' = ______________________

10. Tan 81 degrees 2' = ______________________

Math IV - Worksheet 2

Find the angles for the following values using the trigonometry tables. Answers should be to the nearest minute.

1. Sin ____________________ = .66305

2. Cos ____________________ = .33435

3. Tan ____________________ = 1.15648

4. Cot ____________________ = .93195

5. Sec ____________________ = 3.2368

6. Cot ____________________ = 1.3254

7. Cot ____________________ = 1.4892

8. Tan ____________________ = .79119

9. Csc ____________________ = 1.0640

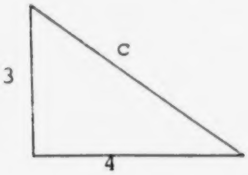
10. Cos ____________________ = .32548

Math IV - Worksheet 3

Find the missing side in the following triangles using the following formulas:

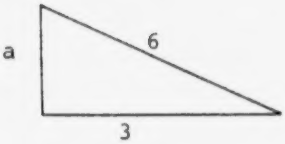
1. $c = \sqrt{a^2 + b^2}$
2. $a = \sqrt{c^2 - b^2}$
3. $b = \sqrt{c^2 - a^2}$

1.



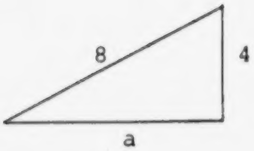
c = ______________________________

2.



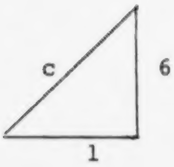
a = ______________________________

3.



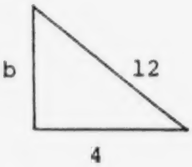
a = ______________________________

4.



c = ______________________________

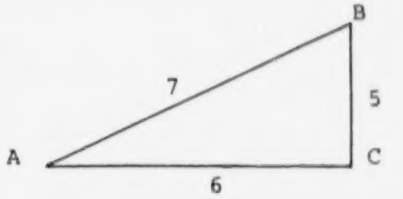
5.



b = ______________________________

Math IV - Worksheet 4

Referring to the figure below, fill in the blanks with the missing words.



1. hypotenuse
2. adjacent
3. opposite

1. Side 7 is the ______________________________ of the triangle.

2. Side 5 is ______________________________ to B.

3. Side 6 is ______________________________ to B.

4. Side 5 is ______________________________ to A.

5. Side 6 is ______________________________ to A.

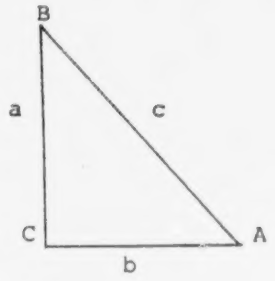
6. The side opposite the right angle is called the

______________________________.

Math IV - Worksheet 5

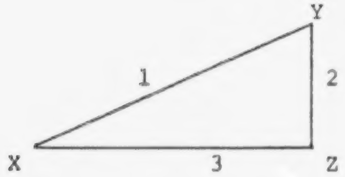
Solve the following right triangles using the Cosine and Sine functions.

1.



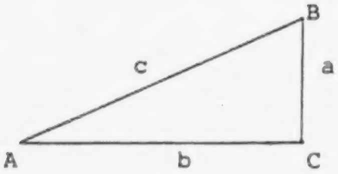
< A = 24 degrees 37'
Side c = 12 in.
< B = ____________
Side a = ____________
Side b = ____________

2.



< X = 40 degrees 0'
Side 1 = 7 in.
< Y = ____________
Side 2 = ____________
Side 3 = ____________

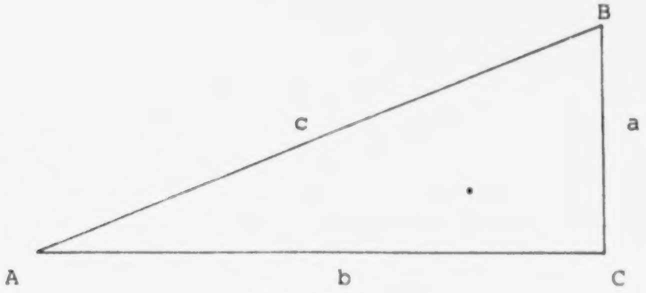
3.



Side b = 6.2 in.
Side c = 10 in.
< A = ____________
< B = ____________
Side a = ____________

Math IV - Worksheet 6

Solve the following problems using the Tangent and Cotangent functions.



1. Side b = 4.38 in.
   Side a = 2 in.
   < B = ____________________
   < A = ____________________

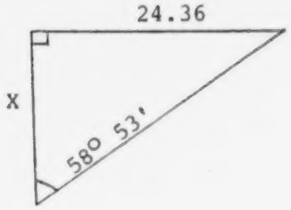
2. < B = 73 degrees 46'
   Side b = 6.8 in.
   Side a = ____________________
   < A = ____________________

3. Side a = 5 in.
   Side b = 8 in.
   < A = ____________________
   < B = ____________________

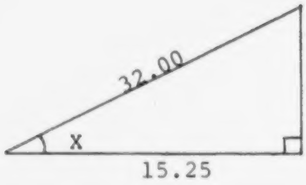
Math IV - Worksheet 7

Solve for x in each of the following right triangles. If x is an angle, find the value of x to the nearest minute.

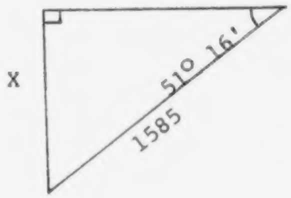
1.



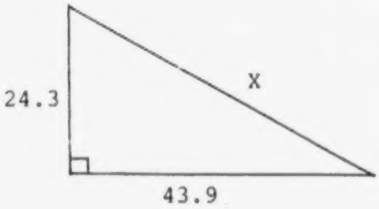
2.



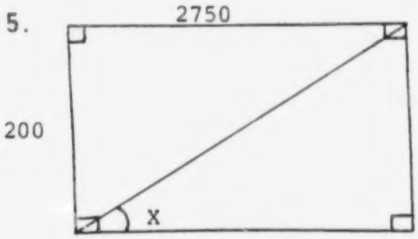
3.



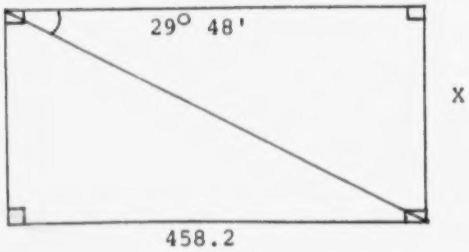
4.



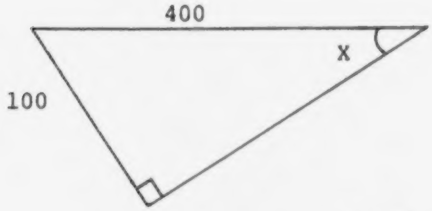
5.



6.



7.



Math IV - Worksheet Answers

Worksheet 1

1. .59482
2. .76041
3. .32492
4. 1.8871
5. 1.4945
6. .08749
7. .14781
8. .74895
9. 1.0515
10. 6.3137

Worksheet 2

1. 41 degrees 30'
2. 70 degrees 30'
3. 49 degrees
4. 47 degrees
5. 72 degrees
6. 37 degrees
7. 34 degrees
8. 38 degrees 30'
9. 70 degrees
10. 71 degrees

Worksheet 3

1. 5
2. 5.196
3. 6.92
4. 6.08
5. 11.31

Worksheet 4

1. Hypotenuse
2. Adjacent
3. Opposite
4. Opposite
5. Adjacent
6. Hypotenuse

Worksheet 5

1. < B = 65 degrees 23'
   Side a = 4.99848"
   Side b = 10.90932"
2. < Y = 50 degrees
   Side 2 = 4.49953"
   Side 3 = 5.36223"
3. < A = 51 degrees 41'
   < B = 38 degrees 19'
   Side a = 7.846"

Worksheet 6

1. < B = 65 degrees 30'
   < A = 24 degrees 30'
2. Side a - 1.97888"
   < A = 16 degrees 14'
3. < A = 32 degrees
   < B = 58 degrees

Worksheet 7

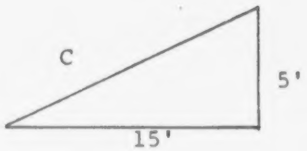
1. 14.70442
2. 61 degrees 30'
3. 1236.41095
4. 50.1766
5. 38 degrees 30'
6. 264.41114
7. 14 degrees 29'

Math IV Test

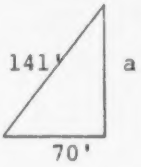
Directions: You may use a calculator to perform addition, subtraction, multiplication, division and square root functions. However, you are required to use the attached trigonometric tables for trigonometric functions.

Give all answers in feet, inches and fractions of an inch.

1. Find the length of side C in the following triangle.



2. Find the length of side A in the following triangle.



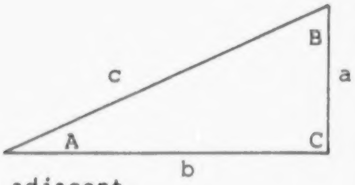
3. The sum of the three angles in a right triangle is equal to ___________ degrees.

4. COS = __________

5. SIN = __________

6. TAN = __________

7. Use the figure to solve the following problems:



   a. With reference to angle A, _____ is on the side adjacent.

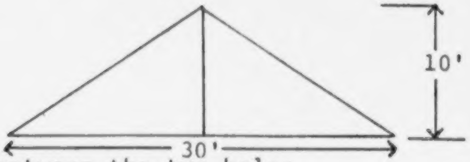
   b. With reference to angle B, _____ is the hypotenuse.

8. The SIN of 27 degrees = ________

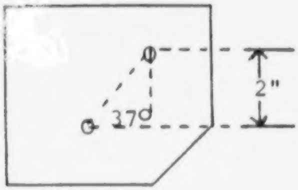
9. The COS of 48 degrees = ________

10. The TAN of 45 degrees = ________

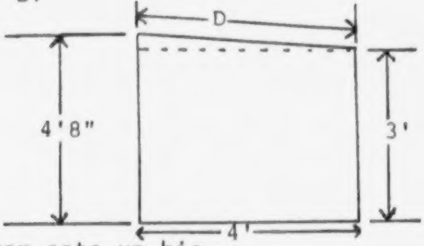
11. The end view of a roof of a building is the triangle shown. Find the angle of the slope of the roof.



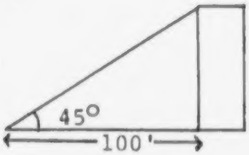
12. In this metal bracket, find the distance between the two holes.



13. If this is a metal template, find the length of D.



14. To find the height of a tall building, a surveyor sets up his transit 100 feet from the base of the building and measures the angle of elevation to the top. What is the height of the building?



15. If a 1/2" eye to eye sling (choker) will lift 2 tons on a straight lift, what will it safely lift at a 45 degree angle?

16. Your job is to fabricate a loading ramp. The ramp must have a change in elevation of 2 feet in a run of 5 feet. How long should the ramp be?

Table A-7 Table of natural trigonometric functions

Angle	Sin	Cos	Tan	Cot	Sec	Csc	
0°	.0000	1.0000	.0000	∞	1.0000	∞	90°
1	.0175	.9998	.0175	57.2900	1.0002	57.2987	89
2	.0349	.9994	.0349	28.6363	1.0006	28.6537	88
3	.0523	.9986	.0524	19.0811	1.0014	19.1073	87
4	.0698	.9976	.0699	14.3007	1.0024	14.3356	86
5°	.0872	.9962	.0875	11.4301	1.0038	11.4737	85°
6	.1045	.9945	.1051	9.5144	1.0055	9.5668	84
7	.1219	.9925	.1228	8.1443	1.0075	8.2055	83
8	.1392	.9903	.1405	7.1154	1.0098	7.1853	82
9	.1564	.9877	.1584	6.3138	1.0125	6.3925	81
10°	.1736	.9848	.1763	5.6713	1.0154	5.7588	80°
11	.1908	.9816	.1944	5.1446	1.0187	5.2408	79
12	.2079	.9781	.2126	4.7046	1.0223	4.8097	78
13	.2250	.9744	.2309	4.3315	1.0263	4.4454	77
14	.2419	.9703	.2493	4.0108	1.0306	4.1336	76
15°	.2588	.9659	.2679	3.7321	1.0353	3.8637	75°
16	.2756	.9613	.2867	3.4874	1.0403	3.6280	74
17	.2924	.9563	.3057	3.2709	1.0457	3.4203	73
18	.3090	.9511	.3249	3.0777	1.0515	3.2361	72
19	.3256	.9455	.3443	2.9042	1.0576	3.0716	71
20°	.3420	.9397	.3640	2.7475	1.0642	2.9238	70°
21	.3584	.9336	.3839	2.6051	1.0711	2.7904	69
22	.3746	.9272	.4040	2.4751	1.0785	2.6695	68
23	.3907	.9205	.4245	2.3559	1.0864	2.5593	67
24	.4067	.9135	.4452	2.2460	1.0946	2.4586	66
25°	.4226	.9063	.4663	2.1445	1.1034	2.3662	65°
26	.4384	.8988	.4877	2.0503	1.1126	2.2812	64
27	.4540	.8910	.5095	1.9626	1.1223	2.2027	63
28	.4695	.8829	.5317	1.8807	1.1326	2.1301	62
29	.4848	.8746	.5543	1.8040	1.1434	2.0627	61
30°	.5000	.8660	.5774	1.7321	1.1547	2.0000	60°
31	.5150	.8572	.6009	1.6643	1.1666	1.9416	59
32	.5299	.8480	.6249	1.6003	1.1792	1.8871	58
33	.5446	.8387	.6494	1.5399	1.1924	1.8361	57
34	.5592	.8290	.6745	1.4826	1.2062	1.7883	56
35°	.5736	.8192	.7002	1.4281	1.2208	1.7434	55°
36	.5878	.8090	.7265	1.3764	1.2361	1.7013	54
37	.6018	.7986	.7536	1.3270	1.2521	1.6616	53
38	.6157	.7880	.7813	1.2799	1.2690	1.6243	52
39	.6293	.7771	.8098	1.2349	1.2868	1.5890	51
40°	.6428	.7660	.8391	1.1918	1.3054	1.5557	50°
41	.6561	.7547	.8693	1.1504	1.3250	1.5243	49
42	.6691	.7431	.9004	1.1106	1.3456	1.4945	48
43	.6820	.7314	.9325	1.0724	1.3673	1.4663	47
44	.6947	.7193	.9657	1.0355	1.3902	1.4396	46
45°	.7071	.7071	1.0000	1.0000	1.4142	1.4142	45°
	Cos	Sin	Cot	Tan	Csc	Sec	Angle

Math IV Test Answers

1. 15' 9 3/4"

2. 122' 4 25/32"

3. 180

4. A/H

5. O/H

6. O/A

7. B

   C

8. .4540

9. .6691

10. 1.000

11. 33.5 degrees

12. 3.323"

13. 4' 4"

14. 100'

15. 1.414 ton

16. 5' 4 5/8" long

Competency:

1. Interpret basic electricity theory and practice as it relates to troubleshooting, repair, and maintenance.

Instructional Objectives:

1. Distinguish between amperes, volts, and ohms.
2. Identify direct current and alternating current.
3. Identify different types of electric service.
4. Describe the importance of making sure that motor ratings are matched to the voltage and phase characteristics of the electrical system.
5. Explain the purpose of switches, circuit breakers, and fuses.
6. Explain the purpose of grounding in electrical systems.
7. Identify safe practices when working with electricity.
8. Identify the effects of electric shock.

Learning Activities:

1. Read What a Journeyman Should Know About Electricity from the National Association of Plumbing, Heating and Cooling Contractors.
2. View the videotapes "Plant Science - 5: Electrical Energy" (NUS Training Corporation) and "Electrical Safety" (Tel-A-Train).
3. View the videotapes "Electrical Equipment - 1" and "Electrical Equipment - 2" (NUS Training Corporation) instead of "Plant Science - 5: Electrical Energy."
4. Complete the Electrical Systems Worksheet.

Evaluation/Checkout:

1. Submit Electrical Systems Worksheet
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. What a Journeyman Should Know About Electricity. Falls Church, Virginia: NAPHCC, 1985. This is available from the National Association of Plumbing, Heating, and Cooling Contractors, P. O. Box 6808, Falls Church, VA 22046.
2. A copy of the worksheet and answers and the test and answers is included with this unit.

Audio-Visual Material:

1. The videotapes "Plant Science - 5: Electrical Energy," "Electrical Equipment - 1," and "Electrical Equipment - 2" are available from NUS Training Corporation. "Electrical Energy" is part of the Pulp and Paper Operations series.

Plant Science - 5 examines the principles of electricity, introducing terms such as voltage, current, resistance, electromotive force, induction, and motor action. The unit teaches Ohm's Law, the elements of the Ohm's Law formula, and the interaction between electricity and magnetism, particularly in relation to the operation of electric motors and generators. The concluding segments illustrate the major parts of an electrical system and demonstrate the operation of a transformer and a solenoid.

Electrical Equipment - 1 introduces the power path in an electrical system, describing the components of the system and explaining their functions.

Electrical Equipment - 2 covers the operation of electrical motors. Types of motors are identified and classified, and the principles of operation of motor controllers and control circuits are explained. Also included is a discussion of basic operator responsibilities for operating electrical equipment.

A workbook is supplied with each unit.

2. The videotape "Electrical Safety" is available from Tel-A-Train, Inc. This program concentrates on the everyday encounters that electricians and other maintenance personnel have with electricity below 600 volts. Case histories are given, and safety attitudes are discussed. Other subjects addressed include circuits, fuses, grounding, lockout, and insulation. At the conclusion of this program, viewers are more aware of the various hazards involved with even minor electrical work. They will understand the different ways electrocution can occur and the best ways to prevent it.

Resources:

1. Books:
    A. Basic Electricity and DC Circuits. Dallas, Texas: Texas Instruments, 1986.
    B. Basic AC Circuits. Dallas, Texas: Texas Instruments, 1981.

2. Audio-Visual Material:
    A. "Anatomy of an Electric Shock" is a videotape available from NAPHCC LaBelle Lending Library, P.O. Box 6808, Falls Church, VA 22046.
    B. "Electrical Lockout/Tagout" is a videotape available from Tel-A-Train, Inc.
    C. "Safety in Electrical Maintenance," and "Electrical Systems" are videotapes available from NUS Training Corporation.
    D. "Basic Electricity I, II, III, IV, and V" and "Electrical Safety" are videotapes available from L & K International Videotraining.
    E. "Basic Electrical Troubleshooting" is a videotape available from Industrial Training, Inc.
    F. "Electrical Safety in Low Voltage Situations" is a videotape available from Marshall Maintenance Productions.

Electrical Systems Worksheet

1. Define ampere, volt, and ohm.

2. Explain the difference between direct current and alternating current.

3. Why are three phase A.C. systems commonly used?

4. What is the purpose of a transformer in an electrical system?

5. How are electric motors protected from overload?

6. Explain why motors should only be connected to systems whose voltage and phase characteristics are the same as the motor nameplate ratings.

7. List seven safety rules that are to be used when working on electrical systems.

8. What are the effects of electric shock?

Electrical Systems Worksheet Answers

1. The ampere is a rate of flow of electricity in a conductor. The volt is the basic unit of electric potential. The ohm is the basic unit of electric resistance or impedance.
2. A direct current system is one in which voltage and current are constant and do not change with time. An alternating current system is one in which the voltage and current change with time.
3. They are more economical for electrical power distribution and because of the simplicity of three phase machines.
4. A transformer is used to change one voltage to another.
5. Through overloads or heaters which interrupt the motor current when this current exceeds the rated full load current of the motor.
6. To avoid overheating and damaging the motor.
7. Answer on pages 10-11 in "What a Journeyman Should Know About Electricity."
8. Electric shock may cause unconsciousness, cessation of breathing, burns of all degrees, and death.

Electrical Systems Test

1. Match the following:

_____ This is comparable to roughness on the inside of the pipes in a water system. a. ampere

b. volt

_____ This is comparable to gallons per minute of water flowing in a pipe. c. ohm

_____ This is comparable to pressure in a water system.

2. When electrical current moves continuously in one direction through a conductor, it is called ____________________.

3. When electrical current moves back and forth through a conductor, it is called ____________________.

4. The most common source of DC voltage is a ____________________.

5. When using an extension cord over 50 feet a voltage drop may occur resulting in the power tool ____________________.

6. _____ When checking pump motor current, you are checking:

   a. amperes
   b. volts
   c. ohms
   d. none of the above

7. _____ True or False - Voltage is the shock factor rather than the amount of current.

8. _____ An equipment ground wire prevents:

   a. a fault inside an electrical device
   b. a circuit breaker from tripping
   c. a shock hazard
   d. current surges

9. Match the following:

_____ Turns electricity on and off	a. amperes
_____ Rate of flow	b. volts
_____ Overloads or heaters	c. ohms
_____ Pressure	d. transformer
_____ Changes one voltage to another	e. motor protection
_____ Resistance	f. switches
_____ Protects electrical wiring from overloads	g. circuit breakers

10. Alternating current is generally produced at a frequency of ____________________.

Electrical Systems Test Answers

1. c.
   a.
   b.

2. Direct Current

3. Alternating Current

4. Battery/cell

5. Running slower and being overloaded easier.

6. a.

7. False

8. c.

9. f.
   a.
   e.
   b.
   d.
   c.
   g.

10. 60 cycles per second

Competency:
1. Describe energy and its relationship to work, power, and efficiency.

Instructional Objectives:
1. Define energy.
2. Define work, power, and efficiency.
3. Describe the relationship between work, power, and efficiency.
4. Explain how heat is converted to power.
5. Solve efficiency problems.

Learning Activities:
1. Read Chapter 6, "Energy" in Conceptual Physics by Paul Hewitt.
2. Read the Information Sheet on Energy.
3. View the videotapes "Energy Conversion" (NUS Training Corporation) and "Plant Science - 6: Science Fundamentals" (NUS Training Corporation).
4. Complete the Energy Worksheet.

Evaluation/Checkout:
1. Submit the Energy Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Material:
1. Hewitt, Paul. Conceptual Physics, 6th Edition. Glenview, Illinois: Scott Foresman, 1989.
2. A copy of the information sheet, and the worksheet and answers is included with this unit.
3. An Instructor's Manual is available for the text containing lecture and demonstration ideas and test questions. In addition, a Test Bank is available with both quantitative and qualitative questions.

Audio-Visual Material:
1. The videotape "Energy Conversion" is available from NUS Training Corporation. This videotape is part of the Plant Science units in the Power Plant Basics series. The Plant Science units cover converting energy from one form to another in the power plant which is the focus of this topic. This requires trainees to become familiar with terms such as mass, weight, density, specific gravity, specific volume, viscosity, temperature, and pressure. Trainees will also learn when and how the properties of matter change; to read pressure and temperature measurements on a variety of scales; and to make conversions between pressure units and between temperature units.

The "Energy Conversion" tape covers the following topics:
1. Energy
2. Kinetic and Potential Energy
3. Energy Conversion and Work
4. Work and Power
5. Efficiency
6. Plant Efficiency

A workbook is supplied with the unit.

2. The videotape "Plant Science - 1: Science Fundamentals" is available from NUS Training Corporation. It is part of the Pulp and Paper Operation series. Some basic scientific principles and their applications in a process facility are introduced here, along with units of measurement for length, time, mass, pressure, temperature, flow, and level. The relationship between force and motion, and the laws that apply to force and motion, the definition of work, and the relationship of work to energy are also covered. The mechanical advantage of the inclined plane and the lever illustrate a discussion of basic machines, including examples of where the mechanical advantages of these basic machines are used in process equipment. A workbook is supplied with the unit.

Resources:
1. Audio-Visual Material:
    A. "Steam Turbines" is a videotape available from NUS Training Corporation. Steam Turbines introduces the principles of typical steam turbine operation. The unit outlines the major components of a turbine and shows how these components work together to convert thermal energy into mechanical energy. Problems associated with turbine operation, procedures to avoid these problems, and corrective action are also covered. A workbook is supplied with the unit.

Energy Information Sheet

The Concept of Work - Work is a measure of accomplishment, such as using high temperature fluids to do work. In a technical sense, it is force acting on a body which displaces the body in the same direction as the direction of the force. As a formula: Work = Force x Distance.

From what was stated above, it is clear that holding up a wall or a ceiling all day long involves no work at all, in a technical sense, because no movement takes place. Likewise, it is impossible to push anything at a constant speed along a frictionless service because there is no reaction force to push against. Surfaces that have very little friction, such as ice, require very little force for movement to take place.

Work is measured in foot-pounds or newton-meters and a newton-meter is also called a joule.

Energy-Kinetic and Potential - Energy is the capacity to do work. There are various forms of energy, such as electrical energy, thermal energy, and mechanical energy. Any body capable of doing work is said to be endowed with energy. There is energy due to motion called kinetic energy. This is the type of energy a moving car has. The ability of a body to do work due to its position is called potential energy. For example, water stored in a dam contains potential energy due to its position, and can be made to do work. Coal and fuel oil also possess potential energy.

Potential energy can be transformed into kinetic energy. Coal and oil can be converted into electrical energy, thermal energy, or chemical energy. During this transformation, energy is not created or destroyed, only transformed from one form to another. This is the law of conservation of energy.

Power - A machine can do work through the use of energy. The rate at which the work is done is called power. The unit of power is the horsepower equal to 550 ft.-lbs per second.

Efficiency - With a machine, we are transmitting and/or multiplying force. By the use of a machine, a large resisting force can often be overcome by the application of a much smaller effort force as in the use of hydraulics and pneumatics. Some machines are more efficient than others. The higher the efficiency of a machine, the lower the proportion of energy wasted as heat. Efficiency equals work done divided by energy used.

Conversion of Heat Energy into Mechanical Energy - The concepts that have been described above can be used to explain how heat energy is converted into mechanical energy. This occurs when the steam turbine is used in power plants for the generation of electricity. Here the stored chemical energy of coal or oil becomes the thermal energy of the steam that is then converted to rotational kinetic energy of the turbine. This mechanical energy is transformed into electromagnetic energy by an electrical generator connected to the turbine shaft. In the last 70 years the efficiency for conversion from stored chemical energy to electrical energy has increased.

In a steam turbine, steam enters the turbine chamber at a certain pressure and temperature and travels through the turbine in a few hundredths of a second. The hot pressurized steam, as it passes through the sets of vanes, loses its thermal energy by pushing against the moving sets of blades. The temperature quickly drops and may be as low as 310 degrees K at the exhaust port. At this point the condenser rapidly converts the steam to water, so the pressure in this region is often less than atmospheric pressure. This lower exhaust temperature increases the efficiency. The water is then returned to the boiler to be converted again into steam and the cycle is repeated.

References:

1. Beiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
2. Bennett, C. Physics Without Mathematics. New York: Barnes and Noble Books, 1970.
3. Inman, F. and Miller, C. Contemporary Physics. New York: Macmillan Publishing Company, 1975.

Energy Worksheet

1. Define energy.

2. Describe work, power, and efficiency.

3. Explain the relationship between energy, work, power, and efficiency.

4. What does the law of conservation state?

5. What is potential energy? Give an example from your work.

6. What is kinetic energy? Give an example from your work.

7. In a certain engine, fuel is burned and the resulting heat is used to produce steam which is then directed against the vanes of a turbine, causing it to rotate. What is the efficiency of the heat engine if the temperature of the steam striking the vanes is 400 degrees K and the temperature of the steam as it leaves the engine is 373 degrees K?

8. If the initial steam temperature in question 7 is 500 degrees K, what is the efficiency of the heat engine?

9. In what way is the heat energy of steam converted to mechanical energy in a steam driven engine in a power plant?

10. Power is ____.

Energy Worksheet Answers

1. The property of a system that enables it to do work.

2. Work is the product of the force exerted and the distance through which the force moves. Power is the rate of doing work. Efficiency is the percent of the work put into a machine that is converted into useful work output.

3. Energy is needed in order to do work. Work is a way of changing energy from one form to another. Power influences how fast work is done and efficiency explains how much of the work of a machine, for example, is translated into useful work.

4. Energy cannot be created or destroyed; it may be transformed from one form into another, but the total amount of energy never changes.

5. Potential energy is the ability of a body to do work due to its position.

6. Kinetic energy is the ability of a body to do work due to its motion.

7. $$\text{Efficiency} = \frac{\text{Work done}}{\text{Energy used}} = \frac{400 \text{ degrees K} - 373 \text{ degrees K}}{400 \text{ degrees K}} = .068 = 6.8\%$$

8. 25%

9. The stored potential energy of coal, oil, or gas becomes the thermal energy of the steam that is then converted through work to rotational kinetic energy in the turbine. This mechanical energy is transformed into electromagnetic energy by an electrical generator connected to the turbine shaft.

10. The rate of doing work.

Competency:

1. Identify the states of matter.
2. Define the properties of solids, liquids, and gases, and perform work related calculations dealing with these properties.

Instructional Objectives:

1. Define matter.
2. Describe the three states of matter.
3. Define element and atom.
4. Define density and elasticity.
5. Distinguish among tensile stress, compressive stress, shear stress and strain.
6. Explain factor of safety for a material.
7. Solve problems dealing with states of matter.
8. Explain Pascal's Law.
9. Explain the operation of an open manometer.
10. State the construction and operation of a bourdon tube gage.
11. Solve problems concerned with liquids at rest and in motion.
12. Explain Bernoulli's Principle.
13. Define viscosity.
14. Differentiate between pressure drop and velocity pressure.
15. Define surface tension.
16. Define buoyancy.
17. State Archimedes' Principle.
18. Explain and apply the specific weight concept.
19. Solve specific weight and density problems.
20. Differentiate between specific gravity and specific weight.
21. Explain what the atmosphere is.
22. Define venturi and explain what it is used for.
23. Define Boyle's Law.
24. Describe the operation of a barometer.
25. Solve problems using absolute and gauge pressure.

Learning Activities:

1. Read Chapter 10, "The Atomic Nature of Matter," Chapter 11, "Solids," Chapter 12, "Liquids," and Chapter 13, "Gases and Plasmas" in Conceptual Physics by Paul Hewitt.
2. Read the Properties of Matter I Information Sheet.
3. Read the Properties of Matter II Information Sheet.
4. Read the Properties of Matter III Information Sheet.
5. View the videotapes "Plant Science - 2: Properties of Matter" (NUS Training Corporation) and "Plant Sciences - 4: Process Dynamics" (NUS Training Corporation) or "Properties and Fluid Flow" (NUS Training Corporation) and "Pressure" (NUS Training Corporation).
6. Complete the Properties of Matter I Worksheet.
7. Complete the Properties of Matter II Worksheet.
8. Complete the Properties of Matter III Worksheet.

Evaluation/Checkout:

1. Submit the Properties of Matter I, II, and III Worksheets.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Material:

1. Hewitt, Paul. Conceptual Physics, 6th Edition. Glenview, Illinois: Scott Foresman, 1989.
2. A copy of the information sheets and the worksheets and answers is included with this unit.
3. An Instructor's Manual is available for the text containing lecture and demonstration ideas and test questions. In addition, a Test Bank is available with both quantitative and qualitative questions.

Audio-Visual Material:

1. The videotape "Plant Science - 2: Properties of Matter" is available from NUS Training Corporation. This videotape is part of the Pulp and Paper Operation series. It focuses on the properties of matter associated with solids, liquids, and gases, and demonstrates how these properties influence process system operation. The molecular structures and related characteristics of solids, liquids, and gases are also discussed. The unit defines and explains mass, weight, density, specific gravity, buoyancy, viscosity, elasticity, and other terms associated with the effects of stress, pressure, and temperature on the three states of matter. A workbook is supplied with the unit.

2. The videotape "Plant Science - 4: Process Dynamics" is available from NUS Training Corporation. This videotape is part of the Pulp and Paper Operations series. It introduces the principles and operating characteristics of liquid, gas, and vapor systems by describing the main parts of a fluid system and the effects of pressure related to static fluids and steady-state flowing fluids. Other subjects covered in this unit include energy conversions that take place in fluid systems, the use of pumps to control flow, common devices to measure process variables, and the effects of resistance and capacitance on operating fluid systems. A workbook is included with the unit.

3. The videotapes "Properties and Fluid Flow" and "Pressure" are available from NUS Training Corporation. These videotapes are part of the Plant Science units in the Power Plant Basics series. The Plant Science units cover converting energy from one form to another in the power plant as the focus of this topic. This requires trainees to become familiar with terms such as mass weight, density, specific gravity, specific volume, viscosity, temperature, and pressure. Trainees will also learn when and how the properties of matter change; to read pressure and temperature measurements on a variety of scales; and to make conversions between pressure units and between temperature units.

The "Properties and Fluid Flow" tape covers the following topics:

1. Mass and Weight
2. Density and Specific Gravity
3. Specific Gravity, Specific Volume, and Viscosity
4. Pressure
5. Fluid Flow
6. Flow Rate

The "Pressure" tape covers the following topics:

1. Pressure and Force
2. Adding Pressure and Pressure Differences
3. Atmospheric Pressure
4. Vacuum
5. Pressure, Volume Calculation
6. Pressure, Volume, and Temperature Calculations.

A workbook is supplied with each unit.

Properties of Matter I Information Sheet

Composition of Matter - Matter is anything that occupies space and has weight. It is composed of atoms of different elements which form molecules. Although there are at this time only 108 known elements, these elements combine to form millions of different kinds of molecules. If two or more molecules group together and maintain their individual chemical identities, they form a mixture. If the group's nature is chemically different than the original's, they become a compound. Examples of compounds are: water, which is composed of two molecules of hydrogen and one molecule of oxygen and is termed H O; or carbon dioxide which is composed of one molecule of carbon and two of oxygen and termed CO . Carbon monoxide, caused by incomplete combustion, has only one molecule of oxygen and is dangerous to breathe for that reason.

Kinetic Theory - Molecules of a substance are in constant motion, because they contain energy, down to a temperature of -460 degrees F. even in solid form. As the temperature increases in the molecule, it moves faster. As the speed of the molecule increases, the distance it is propelled increases.

Cohesion - The force holding the molecules together is very much like a magnetic force and is termed cohesion. The greater the distance between the molecules, the smaller the attraction they exert on each other. Consequently, as the temperature of a substance is increased, the molecules move faster and farther apart from each other. As they move apart, the force holding them together is diminished. This cohesive force holding a solid together will decrease until it isn't strong enough to keep the molecules in a rigid state. The substance turns into its liquid state. Its molecules are now free to flow over one another at will. A further increase in temperature will continue to weaken this bond until there is no cohesive force holding the molecules together at all. Then the substance turns into its vapor or gaseous state. This is known as the kinetic theory of molecules and it is very important that it is understood.

Three States of Matter - So matter, then, comes in three states; solid, liquid, and gaseous. A solid has a definite shape and volume. Its molecules are basically restricted to vibrating, due to its low temperature and high cohesive force.

A liquid has a definite volume, but no definite shape because its molecules are free to flow over each other due to a lower cohesive force. A gas has neither a definite volume nor shape as it has no cohesive force holding its molecules together at all. They are free to expand and fill any container in which they are confined.

Gas Pressure - As you increase the temperature of a gas, you increase the amount of energy each molecule contains. As the energy level increases, the molecule moves with more velocity and to a greater distance. More molecules bombard the walls of the container and also with more strength. This increases the pressure exerted on the container and would show an increase on a pressure gauge installed on it.

Molecular Repulsion - Molecules also repel each other in the same manner as they attract each other. The stronger the repulsion an objects' molecules have to each other, the greater the force required to crush the object. This is the reason buildings have steel beams along with the concrete. The steel beams' molecules have a greater repulsion to each other than do the concretes' and will withstand a much greater compressibility.

Strength of Materials - As was just mentioned, solids vary in terms of a number of qualities or properties that influence their strength. When working with and selecting materials for various applications, it is important to consider the internal structure of the materials. This influences the effect that external forces have on the materials and the ability of the materials to safely handle the external forces. For example, a hose used on a hydraulic system needs to be able to withstand the pressure of the liquid that occurs due to the force of the hydraulic cylinder.

Stress - Applying an external force to a material results in an internal resistance or stress being set up in the material that resists the external force. This force may be trying to change the shape or size of the material. So, stress is the internal resistance to an external force.

If the external forces are trying to stretch the material the internal forces will be resisting the lengthening of the material and the stress set up is called tensile stress. Compressive stress occurs if the external forces try to compress or shorten the material. Since materials vary in these qualities it is important to know what type of stress the materials have to resist. For example, concrete is strong in compression but weak in tension and, therefore, is reinforced with steel bars or rods to withstand tensile stress. Tensile and compressive stresses are caused by in-line forces that are perpendicular to the areas on which they act.

If the external forces act parallel to one another but are not directly in line, then a shear stress will occur and the material may shear. For example, fasteners such as bolts, rivets, and screws are subjected to shear stress.

Strain - A material is strained when it is subjected to a tensile or compressive force. In this case, the material will lengthen or shorten.

Elasticity - A material is distorted more or less by the application of force. The tendency to recover from such distortion whether it be a change of shape or volume or both is called elasticity. For example, a spring has obvious elasticity. The elastic limit of a material refers to the maximum stress that can be applied to an object without it being permanently deformed as a result. When the elastic limit is exceeded, the object may or may not break. Brittle substances like glass or cast iron break at or near their elastic limits. Most metals may be deformed considerably beyond their elastic limits, a property known as ductility. For example, copper is a very ductile metal. When a material exceeds the elastic limit, it will not return to its original size and shape when the force is removed and the deformation remaining is called the permanent set.

A material may eventually fail through fatigue after repeated applications of stresses that are well under its original breaking strength. Minute defects in the internal structure of the material grow a little each time a stress occurs and eventually cracks appear that lead to the material breaking or rupturing.

Factor of Safety for a Material - The ultimate stress or strength of a material is the greatest strength it can withstand without breaking. The allowable or working stress is the portion of the ultimate stress that a material is allowed to carry. For safety reasons, this stress is usually well within the elastic limit. The factor of safety for a material is the ratio between the ultimate stress and the allowable stress.

References:

1. Beiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
2. Bennett, C. Physics Without Mathematic. New York: Barnes and Noble Books, 1970.
3. Inman, F. and Miller, C. Contemporary Physics. New York: Macmillan Publishing Company, 1975.
4. Southern Alberta Institute of Technology. Building Systems Technician - Correspondence Course. Calgary, Alberta, Canada: Power Engineering Department, 1987.

Properties of Matter II Information Sheet

Pressure - In the industrial world of today the term pounds per square inch (PSI) is extensively used, but not always understood as well as some think.

The term means just what it says: pounds on each square inch of surface in question. It doesn't say anything about how many square inches, it only says how many pounds on each square inch. A rectangular tank with dimensions of 10 feet long, 12 feet wide and 20 feet high will have the same PSI as a tank 10 inches long, 12 inches wide and 20 feet high if both tanks contain the same fluid. So, again, PSI simply states the number of pounds on each square inch of the container.

Determining Pressure - To determine the pressure (PSI) in a given container it is a matter of using the right formula and values. The formula is: Pressure (PSI) equals height times density. If the density is given as pounds per cu. in. it can be used. If it is given as pounds per cu. ft. it has to be converted to pounds per cu. in. This is done by dividing the density (pounds per cu. ft.) by 1728 (cu. in per cu. ft.). In many cases we are dealing with a container many feet high. A short cut in this situation would be to divide the density (pounds per cu. ft.) by 144 as there are 144 sq. in. in a sq. ft. and, again, we are concerned with PSI. An example would be water. Water has density of 62.4 pounds per cu. ft. 62.4 / 144 equals .433. Hence, a column of water 1 foot high would exert a pressure of .433 on each sq. in. regardless of the number of square inches involved.

Pressure is always independent of the shape of the container. You can think of fluid pressure as stacks of bricks. The weight under one stack is dependent only on the number of bricks above it. The other stacks do not enter into its weight. This is true with fluids also.

Pascal's Law - Pascal's Law states that pressure exerted on a fluid is transmitted equally in all directions. While this is true, a better way to think about this is that pressure is added equally in all directions and to all levels. Here is an example: A tank 100 feet high is full of water. At the bottom of the tank the pressure is 43.3 PSI (100 x .433). The pressure halfway up is 21.65 PSI (50 x .433). The pressure at the top is 0 PSI. If a pump was connected to this tank and 100 PSI was added to the tank, each gauge reading would increase 100 PSI. The new reading would be the static pressure plus what was added.

Bernoulli's Principle - A very important principle in the field of fluid flow is Bernoulli's Principle. It states, "As the velocity of a fluid increases, the fluids pressure decreases." As we think of natures laws this would make sense. You never gain anything without giving something up in return. As the fluid moves faster, something has to be sacrificed and in this case it's the pressure. This works in both directions. As the velocity is decreased, pressure is increased. This principle explains many phenomena of mechanics. An airplane flies because of this principle. The carburetor in your car meters gasoline to the cylinders using this physical law.

Viscosity - Viscosity is thought of as the internal resistance a fluid has. Another way of saying this is, the resistance a fluid's molecules have to each other. The higher the viscosity, the slower the fluid will flow. Higher viscosity fluids also cause more pressure drop in a conduit.

Pressure Drop - Pressure drop is the pressure a fluid loses while traveling from one point to another in a conduit. Pressure drop increases with increased viscosity, increase in length of pipe, increase in number of fittings and bends, and decrease in inside diameter (cross sectional area) of pipe. A rule of thumb concerning velocity and pressure drop is: Doubling the velocity causes four times as much pressure drop. (Pressure drop increases by the square).

Pressure drop is normally termed Delta P with Delta abbreviated as Δ. It would be written in this manner: (ΔP). In terms of pressure drop it is better to have streamline or laminar flow, but fluids have a tendency to cling to surfaces. This tendency is known as surface film or platting. This film then rises or falls in temperature until it approaches the heat exchanger temperature. It then becomes an insulator. By using increased velocity a turbulent flow can be implemented which will scour the surfaces continually and increase heat transfer considerably.

Specific Weight and Specific Gravity - Specific weight gives a reference for a substance's weight to a standard that we are all familiar with. Water is used for solids and liquids. Air is used for gases. A specific weight of two simply means that the objects weight is twice that of the same volume of water. Or, its density is twice that of water. In the case of gases, a gas with a specific weight (gravity) of two, means a gas with the same volume as that of air would weigh twice as much.

Specific Gravity is essentially the same thing as specific weight EXCEPT that it is used when fluids are being considered.

References:

1. Beiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
2. Bennett C. Physics Without Mathematics. New York: Barnes and Noble Books, 1970.
3. Inman, F. and Miller, C. Contemporary Physics. New York: Macmillan Publishing Company, 1975.
4. Southern Alberta Institute of Technology. Building Systems Technician - Correspondence Course. Calgary, Alberta, Canada: Power Engineering Department, 1987.

Properties of Matter III Information Sheet

The Atmosphere - Even though we can't see or feel the air surrounding us it does have weight and it does occupy space and as such it is a form of matter. By using a device known as a barometer we can measure how much force the air surrounding us is exerting. A barometer is a simple device made of two components, a tube sealed at one end and a container filled with mercury. The tube is completely evacuated (we say then, that it is in a perfect vacuum) and the open end is placed downwards in the mercury. The pressure exerted by the weight of the air on the surface of the mercury forces the mercury up the tube. Gases will not move down past a liquid seal. Consequently, the difference in pressure inside the tube as compared to the pressure outside the tube determines how high up the tube the mercury will rise. If the tube was properly evacuated there will be absolutely no pressure inside the tube. So the pressure difference will be equal to the pressure exerted by the atmosphere. This is relatively easy to determine by use of the basic pressure formula (P = Height multiplied by Density.) The density of mercury is .491 pounds per cubic inch. An example of this situation would be as follows: The barometer has a reading of 27.6 inches or, in other words, the mercury is supported to a height of 27.6 inches by the weight of the air. Substituting in the formula we have H equaling 27.6" and D equaling .491 pounds. 27.6 multiplied by .491 equals 13.55 PSI. Air with a greater density will force the mercury higher in the tube.

The factors that cause air to be less dense include higher temperature air which is less dense because heating a substance causes expansion. Altitude, such as being up on a mountain or in an airplane causes a reduction in density as there are less layers of air to add weight to the air. And humidity added to air causes it to be less dense as steam is less dense than air and humidity is in air in the form of steam. So a mixture of the two will be less dense than air alone.

Pressure and How It Is Measured - Pressure in our industry always means one thing, pounds per square inch. If a journeyman was to ask you how much pressure was showing on the system pressure gauge and you replied "10 pounds per square foot" the journeyman would be confused as the journeyman is use to PSI.

We will be dealing with two different concepts of pressure. Gauge pressure (the pressure that we are all familiar with, which is the pressure that shows on a gauge) and absolute pressure (gauge pressure plus atmospheric pressure.)

The three common methods of measuring system pressures are, a bourdon tube gauge (named after its inventor), an open manometer, and a formula that says the pressure exerted by a fluid is equal to its height multiplied by the density of the fluid.

The bourdon tube gauge and the open manometer both read zero PSI before installation. The open manometer reads zero because the pressure on both legs is equal and liquids always seek the same level. The bourdon tube gauge reads zero because the pressure is the same in the tube as it is surrounding the tube. Therefore, when either instrument is installed in the system they measure the pressure either added to the atmosphere or subtracted from the atmosphere. They never measure the actual pressure in the system. Another way of saying it is, they measure how much the atmosphere is altered.

The proper way to read an open manometer is to measure the difference in the two legs and multiply by the density of the fluid (P=HxD). Using a manometer with water in it, the difference in the elevations of the two legs multiplied by .0361 gives the correct reading in terms of pressure (PSI). This is then stated as (x) number of inches water column (wc) or water gauge (wg).

Water manometers are usually used when small pressures are to be read. Mercury manometers are used where larger pressures are to be read. A water manometer would have to be 34' high to equal a mercury manometer 30" in height. Inclined manometers are used where the pressures are in the hundreds or thousands of an inch wc. or wg. Manometers can either measure pressure or vacuum depending on the way they are connected.

Compound gauges are bourdon tube gauges that read both above and below atmospheric pressure. In other words, they read both pressure and vacuum in inches of mercury.

Determine Absolute Pressure - How you determine the absolute pressure in a system depends on whether the system is in a vacuum or under a positive pressure situation. A vacuum is any pressure below atmospheric. A perfect vacuum is a condition where all the vapors in a system have been removed and on a vacuum gauge would have the same reading as the barometer. This is because vacuum gauges tell how much pressure has been removed from the original atmospheric pressure. A vacuum of 10" HG taken when the barometer reading is 29.92" HG means that 10" HG of pressure was taken away. The system started with 29.92" HG, meaning that 19.92" HG are left. This actually means that a pressure great enough to force a column of mercury 19.92" high is left in the system. Using the formula P=HxD, the pressure in this system is 19.92 x .491 (the density of mercury) or 9.78 PSIA.

To determine the absolute pressure in a system when the system has had pressure added to it requires the gauge pressure and the atmospheric pressure to be added to each other. An example would be 15 PSIG showing on the gauge with a barometer reading of 26" HG. The barometer reading is a pressure of (P=HxD) 26 x .491 = 12.766 plus 15 = 27.766 PSIA because absolute pressure equals gauge pressure plus atmospheric pressure.

References:

1. Beiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
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Properties of Matter I Worksheet

1. What is matter?

2. Name the three states of matter.

3. _____ True or False - Solids have a definite volume and a definite shape.

4. _____ True or False - Liquids have a definite weight and a definite volume.

5. _____ True or False - Gases have a definite weight.

6. What is an element?

7. What causes a substance to be either gas, liquid or solid?

8. What is an atom?

9. How many elements compose a water molecule?

10. How many individual atoms compose a water molecule?

11. Define density.

12. Define elasticity.

13. Distinguish between iron and steel.

14. Why is it more exact to say that steel is dense than to say that steel is heavy?

15. Why does a cupful of water have the same density as a lake full of water?

16. What is an alloy?

17. The formula for density is: density equals mass divided by volume, or weight divided by volume. An object has dimensions of 8" in diameter, 11" in length, and weighs 64 pounds. What is its density?

18. A tank is 6 ft. long, 4 ft. wide, and 5 ft. deep. What is its volume in cubic feet and gallons.

19. The above tank is filled with gasoline. Gasoline has a density of 44 gallons per cubic feet. What is the weight of the gasoline?

20. How many gallons of hydraulic oil will a cylinder with a 6" diameter and a 14" stroke contain when it is fully extended?

21. A tank 10' high with a diameter of 5' is filled with a fluid weighing 10,000 pounds. What is the density of the fluid?

22. In a cubic foot there are ____________ cubic inches.

23. In a cubic yard there are ____________ cubic feet.

24. Which weighs the most, lead or gold? Why?

25. Why is the density of ice less than water?

26. What is the volume of an icebox which is 8 inches long, 12 inches wide, and 10 inches deep? Give your answer in cubic inches.

27. Find the capacity in gallons of a round tank 8 feet high and 7 feet in diameter.

28. A 7 cu. ft. block of material weighs 105 lbs. What is its density?

Define the following and give an example of each term:

29. Mass

30. Tensile Stress

31. Compressive Stress

32. Shear

33. Elastic Limit

34. Ductility

35. Explain the factor of safety for a material.

36. Why would pipe at a very high temperature have less strength than it did at a lower temperature?

Properties of Matter I Worksheet Answers

1. Anything that has weight and occupies space.
2. Solids, liquids, gases
3. True
4. True
5. True
6. Substances that are composed of one kind of atom such as gold or mercury.
7. The rate at which the atoms and molecules are moving about.
8. The smallest particle of an element that has all of the element's chemical properties.
9. Two elements, one hydrogen and one oxygen.
10. Three, two atoms of hydrogen and one of oxygen.
11. The mass of a substance per unit volume.
12. The property of a material wherein it changes shape when a deforming force acts on it and returns to its original shape when the force is removed.
13. Steel is an alloy of iron ore with carbon being added to it.
14. Dense implies a specific volume.
15. Density is the quantity of matter in a unit of volume. This is not restricted to a certain amount.
16. The mixing of two or more metals together to form a new substance.
17. .116 lbs. per cu. in.
18. 120 cu. ft. and 897.6 gallons
19. 5,280 lbs.
20. 1.71 gallons
21. .0295 lbs. per cu. in.

22. 1728

23. 27

24. Gold

25. Ice expands when it gets colder.

26. 960 cu. in.

27. 2302.9 gallons

28. 15 lbs. per cu. ft.

29. - 35. See text and Information Sheet (Properties of Matter I)

36. At higher temperatures substances have less cohesion or attraction between the molecules.

Properties of Matter II Worksheet

1. Liquids exert pressure in which directions?

2. Why do liquids exert pressure?

3. What is the formula for liquid pressure?

4. How do the terms force and pressure differ?

5. The shape of a container has no effect on the pressure contained within. Why?

6. Define capillary force.

7. Define surface tension.

8. State Pascal's Principle.

9. What is the upward force that causes a body immersed in a fluid to float?

10. State Archimedes Principle.

11. A tank is 100 ft. high. If it is filled with fresh water, how much pressure would be exerted on the bottom?

12. If the same tank was filled with gasoline, what would the pressure be? The density of gasoline is 44 pounds per cubic feet. What would it be if it was filled with mercury?

13. An object has dimensions of 25' diameter, 34' in length, and weighs 450 pounds. Will it float or sink?

14. An object with the shape of a cube has 5' sides, weighs 10,125 pounds in the air. What does it weigh in water?

15. A building is 50 feet tall. A hot water heating system in the building is full of water. The height above the gauge on the boiler is 40 feet. A pump is connected to the boiler at gauge level and operated until its gauge reads 100 PSI. What is the pressure at the following levels of the system? (1) Gauge level. (2) 20 feet above gauge level. (3) The top of the system.

16. What is the density of: a cubic inch of water? ________________

a cubic foot of water? ________________

a gallon of water? ________________

a column of water 1 foot high and 1 square inch in area? ________________

17. Why does an iron block sink, but the same weight of iron shaped like a bowl float?

18. Specific weight is a term used to express the ratio of a substance's weight per volume to the weight of an equal volume of a standard. The standard for solids and liquids is a cubic foot of water or a cubic inch of water. The standard for gases is a cubic foot of air. A cubic foot of water weighs 62.4 pounds and a cubic inch of water weighs .0361 pounds. The actual term used for liquids is specific gravity. The way it is used is the same as specific weight. A cubic foot of air weighs .0807 pounds. These terms are especially useful when you discuss pumps and fans. A pump designed to handle water will have to have a motor with a horsepower rating twice as high to handle a fluid with specific gravity of 2. What is the density of a solid object with a specific weight of 13.6?

19. Gasoline has a density of 44 pounds per cubic foot. What is its specific weight?

20. The relief valve installed on a boiler has a circular disc with a diameter of 2.5 inches. When the boiler pressure reaches .30 PSI, what is the total force acting on the disc?

21. Pressure may be measured or expressed in three different terms or units all expressing the same thing.
    1. PSI
    2. In. Hg. (inches of mercury)
        A. A term stating pressure great enough to force a column of mercury to a specific height.
    3. In. of water column. (in. of water column, wc.) or
                             (in. of water gauge, wg.)
        A. A term stating pressure great enough to force a column of water to a specific height.

Do the necessary calculations to convert from one set of units to another Fill in the remaining blanks.

21a. __12__ PSI = ________ in. Hg. = ________ in./ft. water
21b. ________ PSI = ________ in. Hg. = ________ in./ft. water
21c. ________ PSI = ________ in. Hg. = __6 in.__ in./ft. water
21d. __50__ PSI = ________ in. Hg. = __80 ft.__ in./ft. water
21e. ________ PSI = __30__ in. Hg. = ________ in./ft. water

22. As a fluid flows through a piping system there is a loss of pressure due to friction. List four factors which will affect this pressure loss.

23. _____ True or False - Turbulence caused when a fluid flows through a convertor or heat exchanger will increase the efficiency of heat transfer. Why?

24. With the quantity of flow in gpm constant, the velocity of flow will __________________ with a decrease in pipe size.

25. Give one advantage a venturi tube has over the orifice plate when used to meter the flow of fluids.

26. As the velocity of flow increases, due to a constriction, the pressure against the wall of the pipe will be ____________________.

27. Define viscosity.

28. State Bernoulli's Principle.

29. If a solid has a specific weight of 0.75, will it sink or float in water? Explain.

30. Define specific weight.

31. When do we use the term specific gravity?

32. The specific weight of an object is 4.6. What is its density?

33. If an object has a specific weight of 5.4 and a volume of 3 cu. ft., what will it weigh in water?

Properties of Matter II Worksheet Answers

1. In all directions equally.

2. They have weight and are not compressible.

3. P = H x D

4. Force is usually over an entire area while pressure is in lbs. per sq. in.

5. Pressure is equal in all directions and is determined by height x density.

6. Small waves are formed by surface tension inside of fine hairlike tubes and this has the ability to move liquids upward.

7. A liquid will contract to a minimum surface area and the tension formed at the surface is due to molecular forces.

8. As pressure is exerted on a confined fluid, it will release its force equally in all directions.

9. Buoyancy.

10. An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.

11. 43.3 PSI

12. 30 PSI for gasoline and 559.2 PSI for mercury.

13. Float

14. 2,325 lbs.

15. 100 lbs., 91.34 lbs., and 82.68 lbs.

16. .0361, 62.4, 8.34, .433

17. The displacement of water is greater.

18. .490 per cu. in.

19. .705

20. 147.26 lbs.

21. a. 12 = 24.4 in. Hg. = 27' 8 8/16" in./ft. water
    b. .2166 psi = .441 in. Hg. = 6 " in./ft. water
    c. 34.64 psi = 70.54 in. Hg. = 80' in./ft. water
    d. 50 psi = 101.8 in. Hg. = 115'
    e. 14.71 psi = 30 in. Hg. = 34' in./ft. water

22. Viscosity of a fluid, length of pipe, velocity, size and type of pipe, number and types of fittings, valves and bends.

23. True. It removes the surface film.

24. Increase

25. Less turbulence with a correspondingly less net pressure drop.

26. Less

27. Viscosity is the internal resistance that a substances' molecules have to each other.

28. As the velocity of a fluid increases, the pressure decreases.

29. It will float. The solid weighs only 75% of the water it is immersed in and will then be three-fourths under water and one-fourth out of the water.

30. Specific weight tells you how many times, more or less, an object weighs compared to an equal VOLUME of the standard.

31. Specific gravity is used when fluids are being compared.

32. 287.04 lbs. per cu. ft. or .166 lbs. per cu. in.

33. 823.68 lbs.

Properties of Matter III Worksheet

1. What is a barometer used for?

2. Define atmospheric pressure.

3. What causes atmospheric pressure?

4. How does a barometer operate?

5. Define Bernoulli's Principle.

6. Explain how an airplane is supported in air.

7. What is buoyancy?

8. What does Boyle's Law tell you?

9. How does plasma differ from the other states of matter?

10. What keeps the gases in our atmosphere from escaping our atmosphere?

11. When liquid is lifted up in a pipe by a pump, what force causes this to happen?

12. If you compress a tire to twice its volume, by how much will the gas pressure increase (disregard temperature changes?)

13. How high will a helium-filled balloon rise in the atmosphere?

14. As a fluid flows thru a constriction in a pipe (reduction in pipe size) what happens to the pressure?

15. What is the pressure at the bottom of the ocean when the level is 4000 ft. from the surface? (ocean water has a density of 64 lbs. per sq. ft.)

16. What is standard atmospheric pressure?

17. If a liquid only half as dense as mercury were used in a barometer, how high would its level be on a day of normal atmosphere pressure?

18. If a diver loses air when at a depth of 5000 ft. there will be some disastrous results. What are they and why do they occur?

19. A cubic foot of wood and a cubic foot of iron are placed in a container of water. The wood floats but the iron does not. Why?

20. What is the difference between pressure and total force?

21. What is a venturi and what is it used for?

22. How does an aneroid barometer operate?

23. What causes changes in atmospheric pressure?

24. The barometer reading is 28" HG. The gauge reading is 10 PSIG. What is the absolute pressure in the system?

25. The barometer reading is 31" HG. The vacuum gauge reads 15' HG. What is the absolute pressure in the system?

26. The mercury manometer has a reading of 15" HG positive. No barometer reading was given. What is the absolute pressure in the system?

27. A water manometer has a reading of 12" wc. How much pressure is this?

28. A water manometer has a reading of 45" wc. vacuum. The barometer reading is 27" HG. What is the absolute pressure?

Properties of Matter III Worksheet Answers

1. To measure atmospheric pressure.

2. The weight of the air above the earth, usually given at sea level.

3. Weight of air.

4. The barometer "balances" when the weight of the liquid in the tube exerts the same pressure as the atmosphere outside. The mercury is pushed up into the tube of a barometer by atmospheric pressure.

5. The pressure in a fluid decreases as the speed of the fluid increases.

6. The top of the wing has more surface than the bottom so the air must travel faster to go over the top. As the velocity increases, the pressure will decrease.

7. The force that causes an object to float.

8. The product of pressure and volume is a constant for a given mass of confined gas regardless of changes in either pressure or volume individually, so long as temperature remains unchanged.

9. The atoms and molecules that make it up are ionized, stripped of one or more electrons as a result of the more violent collisions at high temperatures. The particles can exert electromagnetic forces on one another.

10. Weight of the gases and gravity.

11. Atmospheric pressure.

12. Two times.

13. Until the weight of the air displaced is equal to the helium.

14. Decreases

15. 1,777.7 lbs. per sq. in. or 256,000 per sq. ft.

16. 14.7 lbs.

17. 59.87"

18. His/her suit will collapse and he/she will be crushed due to the weight of the water. Lack of oxygen will also cause death.

19. Due to the weight per sq. in.

20. Pressure is in PSI while total force equals PSI plus total area.

21. It is an instrument used to cause liquid velocity to increase when going through an orifice. This causes pressure to decrease.

22. A small metal box is partially exhausted of air and has a slightly flexible lid that bends in or out with changes in atmospheric pressure.

23. Clouds, wind, elevation

24. 23.748 lbs. psia

25. 7.856 lbs. psia

26. 22.065 lbs. psia

27. .4332 lbs.

28. 11.632 psia

Competency:

1. Interpret the relationship among temperature, heat, and expansion.
2. Describe heat transfer.

Instructional Objectives:

1. Differentiate between heat and temperature.
2. Explain what a BTU is.
3. Define specific heat.
4. Explain the concept of expansion.
5. Describe what a bimetal is.
6. Solve problems concerned with the expansion of metals.
7. Solve problems concerned with the relationship between temperature and pressure.
8. Define conduction, convection, and radiation.
9. Explain Newton's Law of Cooling.
10. Explain "the greenhouse effect."
11. Solve problems dealing with the relationship between temperature, volume, and pressure.

Learning Activities:

1. Read Chapter 14, "Temperature, Heat, and Expansion" and Chapter 15, "Heat Transfer" in Conceptual Physics by Paul Hewitt.
2. Read the Temperature and Heat Information Sheet.
3. View the videotape "Temperature and Heat" (NUS Training Corporation) or the videotape "Plant Science - 3: Heat" (NUS Training Corporation).
4. Complete the Temperature and Heat Worksheet.

Evaluation/Checkout:

1. Submit the Temperature and Heat Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Material:

1. Hewitt, Paul. Conceptual Physics, 6th Edition. Glenview, Illinois: Scott Foresman, 1989.
2. A copy of the information sheet and the worksheet and answers is included with this unit.
3. An Instructor's Manual is available for the text containing lecture and demonstration ideas and test questions. In addition, a Test Bank is available with both quantitative and qualitative questions.

Audio-Visual Materials:

1. The videotape "Temperature and Heat" is available from NUS Training Corporation. This videotape is part of the Plant Science units in the Power Plant Basics series. The Plant Science units cover converting energy from one form to another in the power plant. This requires trainees to become familiar with terms such as mass, weight, density, specific gravity, specific volume, viscosity, temperature and pressure. Trainees will also learn when and how the properties of matter change; to read pressure and temperature measurements on a variety of scales; and to make conversions between pressure units and between temperature units.

   The "Temperature and Heat" tape covers the following topics:
   1. Temperature Effects
   2. Fahrenheit and Celsius Temperature Scales
   3. Rankine and Kelvin Temperature Scales
   4. Heat
   5. Conduction, Convection, and Radiation
   6. Heat Transfer

   A workbook is supplied with the unit.

2. The videotape "Plant Science - 3: Heat" is available from NUS Training Corporation. This videotape is part of the Pulp and Paper Operations series. It teaches the principles of heat transfer including effects of heat, the relationship between temperature and thermal energy, and the effects of temperature differences on heat transfer. Sensible heat, latent heat, and the effects of pressure on boiling are also covered. The unit also introduces the three modes of heat transfer and discusses the heat transfer process that takes place between two fluids separated by a solid boundary. A workbook is supplied with the unit.

Temperature and Heat Information Sheet

Temperature and Heat - Many people use temperature and heat as one and the same even though there is quite a difference between them. Temperature is defined as the measurement of the average molecular activity of a substance, while heat is the sum of the molecules and how fast they are moving. A good example of this is a cup filled with 200 degree water does not begin to contain the amount of heat a bathtub filled with 100 degree water contains.

According to the Kinetic Theory of Matter, as you add heat to a substance, it's molecules gain energy and move faster. As they move faster the distance between the molecules increases. This results in expansion. The greater the mass the more heat it takes to cause this expansion. Also the higher the specific heat a substance has the more heat it will absorb and the quicker it will increase in temperature.

If enough heat is supplied to convert the substance from a solid to liquid, the force of cohesion is overcome and the substance is able to flow. If further heat is added the liquid will become a gas. At the other extreme, absolute zero is considered to be the point molecular motion or vibration ceases.

The BTU and Specific Heat - There is a very close relationship between these two terms. The BTU is a standard for measuring heat transfer. It is the amount of heat it takes to raise one pound of fresh water one degree Fahrenheit. Specific heat is essentially the same thing, but it tells you how many BTU's it takes to raise one pound of anything one degree Fahrenheit. The higher the value of the specific heat of a substance the greater the amount of heat required to raise the temperature of a given mass of the substance.

Linear Expansion of Solids - Nearly all solids will expand when their temperature increases. If a rod or pipe of a given length is raised in temperature, its increase in length will be directly proportional to its initial length and to the rise in temperature. This increase in length is called linear expansion. The coefficient of linear expansion refers to the change in length per unit length per degree rise in temperature.

Change of length = original length x coefficient of linear expansion x rise in temperature.

On the practical side, when steam piping is erected the expected expansion is calculated and then allowance is made for this expansion by the use of expansion bends or joints.

Transfer of Heat - Transfer of heat occurs by conduction, convection and radiation. Conduction involves the flow of heat from molecule to molecule within a substance, or from one substance to another that are in contact. For example, if the end of a piece of iron is in contact with a source of heat, the whole piece will eventually become warm due to conduction. The highest rate of conductive heat transfer is obtained in dense materials due to the closeness of the molecules. For this reason, metals are good conductors of heat.

In convection, the transfer of heat occurs by the movement of a liquid or gas. Water in a boiler is heated by means of convection currents. The part of the water in contact with the hot tube walls or shell will be heated and will be displaced by cooler water which in turn is heated and displaced. If a pump or fan causes the movement of the liquid or gas, forced convection occurs. The fact that convection occurs within a fluid is a factor to consider when attempting to prevent a flow of heat. In this case insulation is used to prevent the flow of air, for example, because still air is a good insulator.

Radiation refers to the transmission of electromagnetic waves. A typical example of radiation is heat reaching the earth from the sun. Upon striking the earth's surface, the energy is absorbed and converted to heat.

Heat Transfer and Steam Generation - In a boiler used to generate steam, fuel is burned in the furnace at very high temperature and radiates its heat to the boiler shell and tubes and passes through the metal by conduction. The water in contact with the metal of the shell and tubes then becomes heated and less dense than the colder water above it. This causes the heated water to rise upward to the surface and the colder water to flow downward. The currents thus set up in the water contained in the boiler are called convection currents.

As the water becomes hotter the circulation increases. Soon steam bubbles start to form on the hot metal and these rise very rapidly due to their low density relative to the water which rushes in to replace the space they have vacated. The steam bubbles reach the surface of the water and burst into the steam space above the water before being discharged out the steam outlet of the boiler (Building Systems Technician, p. 17).

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1. Beiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
2. Bennett, C. Physics Without Mathematics. New York: Barnes and Noble Books, 1970.
3. Inman, F. and Miller, C. Contemporary Physics. New York: Macmillan Publishing Company, 1975.
4. Southern Alberta Institute of Technology. Building Systems Technician - Correspondence Course. Calgary, Alberta, Canada: Power Engineering Department, 1987.

Temperature and Heat Worksheet

1. Define temperature.

2. Define heat

3. A thermometer is a device used for measuring temperature. How does it actually do this?

4. What is a British Thermal Unit (BTU)?

5. What temperature is the warmest water in a lake that is not frozen all the way to the bottom?

6. What does the term specific heat mean?

7. Why does water expand as it is heated?

8. What is a bimetal? Give some examples of how it is used in our industry.

9. The coefficient of expansion for steel is .0000067. How much will a length of pipe 200 ft. long, installed at a temperature of 70 degrees and operated at a temperature of 300 degrees expand?

10. The coefficient of expansion for copper is .0000095. If the pipe in question (9) was made of copper, how much would it expand?

11. Why does a piece of metal become warm when you strike it with a hammer?

12. What is the temperature in Fahrenheit of absolute zero?

13. How does the specific heat of water compare to the specific heat of other materials?

14. Which expands most with increases of temperature, solids or liquids?

15. Which contains the most heat, a cup of water at 200 degrees, or a bathtub full of water at 50 degrees? Why?

16. Why does the pressure of a gas in a confined container increase with an increase of temperature?

17. As air is compressed, its temperature is greatly increased. Why?

18. The ring gear on some flywheels are "shrink fitted." How is this done?

19. The specific heat of ice is .53. How many BTU's will it take to raise 200 lbs. of ice from 0 degrees to 32 degrees?

20. Why does ice form on the top of a pond instead of on the bottom?

21. Which generally expand the most when heated, solids or liquids? Why?

22. Define conduction.

23. Define convection.

24. Define radiation.

25. The higher you go in an airplane (closer to the sun) the colder it gets. This doesn't seem to make sense. Explain why this is so.

26. Explain the "greenhouse theory".

27. Of the three common states of matter, which is the best insulator and why?

28. State Newton's Law of Cooling.

29. What do the Laws of Thermodynamics say about the efficiency of engines?

30. What does the symbol ΔT mean?

31. You can bring water to a boil in a paper cup. Why doesn't the paper cup burn first?

32. When air is compressed by an air compressor it becomes very hot. Why?

33. As a volume of air is warmed it expands. Is it also true then, that if you expand a volume of air it will increase in temperature Explain your answer.

34. What would be the most efficient color for a radiator?

35. The construction of a thermos jug is as follows: it is a glass container with double walls with a sealed area between the walls. One of the walls is coated with a silver colored coating. A good jug has a vacuum between the walls. Explain why the jug is constructed in this fashion.

36. A house with a hot water heating system in it cannot be satisfactorily heated on a cold day. The boiler temperature is increased by 40 degrees and now it heats satisfactorily. Explain why.

37. In a typical room, the difference in temperature between the floor and ceiling is 4-5 degrees with the ceiling being warmer than the floor. Why?

38. A test tube filled with water has an ice cube held to the bottom with a small weight. The tube is heated at the top until it comes to a boil. The ice cube melts very slowly. Why?

39. A snow making machine consists of a mixture of compressed air and water blown thru a nozzle (venturi). The temperature of the mixture may well be far above freezing, yet crystals of snow are formed as the mixture is ejected from the nozzle. Explain why.

40. Wood is a better insulator than glass, yet fiberglass is used as a building insulator. Why?

Temperature and Heat Worksheet Answers

1. Measurement of the movement of molecules at a given point.

2. The energy that flows from a substance of higher temperature to a substance of lower temperature.

3. By the expansion and contraction of the fluid, mercury or alcohol. Mercury expands more than glass so when it is warmed it expands up the tube.

4. The heat required to raise 1 lb. of water 1 degree Fahrenheit.

5. 39 degrees

6. The quantity of heat per unit mass required to raise the temperature of a substance by one degree Fahrenheit.

7. The molecules move further apart when heated.

8. Two strips of different metals are welded or riveted together, and when heated, one side of the strip becomes longer than the other causing the strip to bend into a curve. Regulate a valve or close a switch.

9. 3 11/16 inches

10. 5 4/16 inches

11. The molecules in the iron move faster and warm up.

12. Minus 460 degrees

13. It has a very high capability for storing heat, more so than only a few uncommon materials.

14. Liquids

15. Bathtub full of water. There is more molecular kinetic energy in the bathtub.

16. The molecules tend to move farther apart when heated.

17. The heat of compression taken from the compressor plus the energy used to compress the air is added to the temperature.

18. The flywheel is heated, put on the shaft, and when it cools it contracts and tightens.

19. 3392 BTU

20. The more dense water is at the bottom and ice starts to freeze at the top first.

21. Liquids because the molecules are further apart.

22 - 26. See the text.

27. Gas because the molecules are further apart.

28. See the text.

29. The energy output of an engine cannot exceed the energy input. The closer the two are the more efficient the engine is.

30. Temperature difference.

31. The water inside absorbs the heat.

32. The heat of the compressor plus the compression heats the air.

33. No. Expansion tends to cool the air.

34. Black

35. Radiation is prevented by the silvered surfaces and conduction and convection are prevented by the vacuum.

36. The heat loss is now equal to the heat gain.

37. Warm air rises, it is less dense.

38. Water is a very poor conductor of heat.

39. As the air is forced through the nozzle it then expands very rapidly and this promotes a cooling effect.

40. It holds the air in between the glass and acts as a good insulator.

Competency:
1. Explain change of state.
2. Describe how heat influences change of state.
3. Demonstrate the use of steam tables.

Instructional Objectives:
1. Define melting and boiling.
2. Define condensation and evaporation.
3. Differentiate between latent and sensible heat.
4. Explain the difference between boiling and evaporation.
5. Solve problems concerned with melting, boiling, evaporation and condensation.
6. Define saturated and superheated steam.
7. Calculate the amount of steam necessary to accomplish a task given a particular pressure.
8. Demonstrate the ability to use steam tables.

Learning Activities:
1. Read Chapter 16 "Change of State" in Conceptual Physics by Paul Hewitt.
2. Read the Change of State Information Sheet.
3. Read the information your instructor gives you on Steam Tables.
4. View the videotape "Water/Steam Properties" (NUS Training Corporation) and "The Steam Tables" (NUS Training Corporation).
5. Complete the Change of State Worksheet.

Evaluation/Checkout:
1. Submit the Change of State Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Material:
1. Hewitt, Paul. Conceptual Physics, 6th Edition. Glenview, Illinois: Scott Foresman, 1989.
2. A copy of the information sheet and the worksheet and answers is included with this unit.
3. An Instructor's Manual is available for the text containing lecture and demonstration ideas and test questions. In addition, a Test Bank is available with both qualitative and quantitative questions.
4. Information on and how to use steam tables is available in Standard Boiler Room Questions and Answers by Elonka and Higgins and in Building Systems Technician by the Southern Alberta Institute of Technology.

Audio-Visual Materials:

1. The videotapes "Water Steam Properties" and "The Steam Tables" are available from NUS Training Corporation. These videotapes are part of the Plant Cycle units in the Power Plant Basic series. The Plant Cycle units explain how the properties of water and steam change as fluid flows through the various plant cycle components. Several concepts are described: the thermodynamics of increased enthalpy in the boiler and enthalpy drop in the turbine; how the properties of water and steam are affected by changes in temperature and pressure; and how problems associated with temperature and pressure can be avoided. Trainees will learn how to look up values for the properties of water and steam in the steam tables and to calculate efficiency and heat rate.

   The "Water/Steam Properties" tape covers the following topics:
   1. The Energy Flow Path and Plant Cycle
   2. Definition of Terms
   3. Subcooled Water
   4. Steam/Water Mixture
   5. Superheated Steam
   6. Pressure

   "The Steam Tables" tape covers the following topics:
   1. Introduction to the Steam Tables
   2. Using the Saturation Tables
   3. The Superheated Steam Tables
   4. Superheated Steam Tables and Conversion Factors

   A workbook is supplied with each unit.

Change of State Information Sheet

Change of State - A substance can exist as a solid liquid, or gas. Which phase or state occurs depends on the temperature and pressure of the substance. If you heat a solid substance, its temperature rises until a particular temperature is reached and the substance begins to melt. During this melting process, heat continues to be added but the temperature remains the same. When all of the solid turns to liquid the temperature begins to rise again until a higher temperature is reached and the liquid begins to turn to a vapor. Once again, the temperature remains constant during this process. The change from solid to a liquid and liquid to a gas is called change of state. The process also works in reverse, from a gas to a liquid to a solid, again at a constant temperature.

The change of state from solid to liquid is known as melting, from liquid to gas is known as evaporation. In reverse, the change of state from gas to liquid is condensation and from liquid to solid is freezing. The melting point is the temperature at which a solid changes to a liquid and the change from a liquid to a solid is the freezing point. The temperature at which a liquid changes to a gas is the boiling point and from a vapor to a liquid is the condensation point.

A liquid will have a different boiling point as the pressure exerted on it changes. As you increase the pressure on a liquid, the boiling temperature increases. The reverse is also true. As the pressure is decreased, the temperature at which it boils is also decreased.

Sensible Heat - This is the heat that changes the temperature of a material but does not change its form. In other words, it is the heat that causes an increase in the temperature of a substance without changing its state.

Latent Heat - This is the heat required for a material to change its state, as ice to water, and water to steam. It is latent or hidden heat since it does not cause a change in temperature.

Flash Steam - When a liquid at a high temperature and high pressure enters an area of low pressure, a portion of the liquid changes to vapor instantly. This is termed flashing. If the fluid is water it is termed flash steam. In order to flash to steam it must absorb heat, in this case latent heat. It absorbs this heat from the remaining liquid and causes a cooling effect on the remaining fluid. We use this principle to cool hot condensate down enough that it can be pumped without boiling in the suction of the pump (cavitation).

Saturation Temperature, Saturated Steam, and Superheated Steam - The change of state from water to steam takes place at the saturation temperature or boiling point influenced by the pressure acting on the water surface. Water at the saturation temperature corresponding to a particular pressure is called saturated water and the steam produced is saturated steam. If the steam does not contain any particles of water then it is called dry saturated steam. If the steam has particles of water suspended in it, it is called wet saturated steam. Saturated steam is just at the temperature of the change of state from liquid to vapor and any loss of heat without a drop in pressure immediately starts to condense it back to water.

Saturated steam may contain no water particles in suspension as it leaves the boiler. As the steam begins to lose heat, however, and falls in temperature condensation loss in the steam line occurs. By heating the dry saturated steam to a higher temperature than that corresponding to its pressure the losses can be avoided or minimized. This can be accomplished by passing saturated steam through tube coils exposed to furnace heat. Steam thus raised in temperature is superheated and will have to drop in temperature by the amount of its superheat before it begins to condense. This is of benefit to situations where steam has to be transmitted long distances to equipment without excessive condensation losses as in power plant operation or process plant operation.

Steam Tables - The thermodynamic properties of steam as sensible and latent heat and saturation temperature, are presented in steam tables. These values are used to solve problems involving the use of steam.

References:

1. Reiser, A. Modern Technical Physics. Menlo Park, California: The Benjamin/Cummings Publishing Company, 1979.
2. Bennett, C. Physics Without Mathematics, New York: Barnes and Noble Books, 1970.
3. Elonka, S. and Higgins, A. Standard Boiler Room Questions and Answers. New York: McGraw-Hill, 1982.
4. Inman, F. and Miller, C. Contemporary Physics. New York: Macmillan Publishing Company, 1975.
5. Southern Alberta Institute of Technology. Building Systems Technician - Correspondence Course. Calgary, Alberta, Canada: Power Engineering Department, 1987.

Change of State Worksheet

1. Why is evaporation a cooling process and condensation a warming process?

2. Why do you feel uncomfortably warm on a humid or muggy day?

3. What is the difference between evaporation and boiling?

4. Why does the temperature at which a liquid boils depend on atmospheric pressure?

5. Why is it necessary to use a pressure cooker up in the mountains rather than at sea level?

6. How can water be made to boil and freeze at the same time? Ask your instructor about sublimation.

7. Why does adding antifreeze to water lower the temperature at which freezing takes place?

8. When water freezes, is energy absorbed or released by the water?

9. Is the food compartment in a refrigerator cooled by vaporization or by condensation of the refrigerating liquid?

10. Why will warmer air support a greater amount of water vapor?

11. Can you see steam?

12. Distinguish between absolute humidity and relative humidity.

13. On cold days the windows in your home sometimes get wet on the inside. Why?

14. What is the principal difference between a cloud and fog?

15. Why is the canvas cover on a canteen wetted before being used?

16. Temperature is defined as the measurement of the average molecular activity. Why is that important when trying to understand evaporation?

17. What does the term pressure-temperature mean?

18. Why does the temperature of boiling water stay the same all the time the water is boiling?

19. What is the boiling temperature of water?

20. Why might an astronaut's blood boil if he stepped out of his capsule without his pressurized space suit?

21. How does melting ice change the temperature of the air?

22. Why will spraying fruit trees with water before a frost help to protect the fruit from freezing?

23. Air conditioning units contain no water whatever, yet it is common to see water dripping from them when they're running on a hot day. Explain this.

24. Does it take more BTU's to boil a pound of 212 degree water at atmospheric pressure than to melt a pound of ice at 32 degrees? How many more?

25. The following questions will be answered using the steam tables.

PSIG	PSIA	SAT. TEMP.	SEN. HEAT	LAT. HEAT	TOT. HEAT	DEN.
15						
	45					
		364				
			180			
				1021		
					1200	
						.0474

26. The steam tables are more appropriately known as enthalpy tables. Enthalpy means the amount of heat in one pound of a substance above a reference level. In the case of water the reference point is 32 degrees. When using the tables you find the amount of heat for one pound and multiply for the number of pounds involved. How many BTUs will it take to take 50 pounds of water at 80 degrees and turn it into steam at 15 PSIG?

27. A unit operates at a pressure of PSIG. It causes 30 pounds of steam an hour to condense and cool to 193 degrees. How many BTUs are given off?

28. Feed water enters a high pressure boiler at a temperature of 373 degrees. The boiler delivers 350,000 pounds of steam an hour at 585 PSIG. How many BTUs per hour are given off?

29. A boiler contains 400 pounds of water at 240 degrees. The boiler operates at a pressure of 140 PSIA. The boiler operates long enough to evaporate 100 pounds of water. How many BTUs does it take to do this job?

30. How many pounds of condensate does a pound of steam make?

31. What does the term saturated steam mean?

32. What does the term superheated steam mean? Why is it used?

33. A pipe line has steam flowing thru it at a pressure of 60 PSIG and a temperature of 308 degrees. There is a natural heat loss thru the insulation of 100 BTUs. What is the cause of this heat loss? What could be done to avoid this result?

34. As the pressure over a liquid is increased the saturation temperature is (increased) or (decreased).

35. As the pressure over a liquid is increased the sensible heat is (increased) or (decreased).

36. As the pressure over a liquid is increased the latent heat is (increased) or (decreased).

37. As the pressure over a liquid is increased the total heat is (increased) or (decreased).

38. What is the saturation temperature of water at a partial pressure of 10" HG. when the barometer is standard?

39. The boiler gauge reads 25 PSIG. The barometer reads 22" HG. How many cubic feet does one pound of steam occupy at that condition?

Change of State Worksheet Answers

1. Molecules move very fast near the surface and overcome surface tension and escape to turn into a gaseous state. This change of state causes cooling. Gas molecules near the surface of a liquid are attracted to the liquid and strike the surface with increasing kinetic energy. This energy is absorbed by the liquid and increases the temperature of the liquid.

2. The humidity in the air slows up the evaporation process and increases the condensation process.

3. Evaporation takes place at the surface of a liquid and can take place at a low temperature. Boiling depends on pressure as well as temperature. It takes place from the bottom of the liquid.

4. In order to overcome pressure at the top of the liquid and escape into the atmosphere the proper temperature must be reached.

5. The higher you are in the atmosphere the lower the boiling temperature, so it takes longer to cook.

6. By placing water in a vacuum jar and reducing the pressure slowly by a vacuum pump. The water will first boil and then freeze at the same time.

7. It causes the formation of ice crystals to slow down by having the molecules of alcohol keep the water molecules from joining together.

8. Released.

9. Vaporization - the liquid changes to a gas and absorbs the heat from the products put in the freezer.

10. The molecules are moving faster and remain in the gaseous state. Warm air will support greater amount of water vapor in the gaseous state.

11. Steam is an invisible gas.

12. Absolute humidity is the percentage of water vapor in a unit volume of air. Relative humidity is the amount of water vapor in the air as to what it could hold at that temperature.

13. Warm air touches the cool window and loses its water vapor due to the cooler temperature.

14. Condensation takes place to form a cloud as warm air rises. Fog is caused by the cooling (over land) of warm air.

15. Canvas will absorb the water and as air passes it causes water to evaporate. The temperature of the cloth then decreases and cools the metal, which in turn cools the water within.

16. The fastest moving molecules are those which escape from the liquid and cause evaporation. Those molecules which remain have their temperature lowered because of the heat loss to the escaping molecules.

17. As pressure increases so does temperature.

18. Because the pressure doesn't change. As more heat is added the water tends to boil faster and this tends to cool the liquid.

19. 212 degrees Fahrenheit at sea level.

20. Atmospheric pressure is removed and thus the blood will boil at a lower temperature.

21. The melting ice is changing from a solid to a liquid and thus it absorbs 144 BTUs per lb. The warmer air gives up the BTUs to the ice.

22. As the water freezes it forms an insulation blanket and when the water freezes it releases heat to the fruit.

23. The warm air comes in contact with the cool coils. It then cools down, cannot hold as much moisture as it did, so it deposits it on the coils.

24. 826.4 more

25.

PSIG	PSIA	SAT. TEMP.	SEN HEAT	LAT. HEAT	TOT. HEAT	DEN.
15	30	250.18	218.82	945.3	1164.1	.0728
30.3	45	274.44	243.36	928.6	1172	.1065
145.3	160	364	335.6	858.5	1194.5	.3529
0.0	14.696	212	180	970.4	1150.4	.03732
25.85	2	126	94	1021	1115	.00576
225.3	240	397.37	372.12	828.5	1200	1.92
4.3	19	225.2	193.4	961.1	1155	.0474

26. 55,793.5

27. 27,931.3

28. 302,540,000

29. 133,240

30. 1 lb.

31. Water at the saturation temperature corresponding to a particular pressure is called saturated water and the steam produced is saturated steam.

32. Steam with more sensible heat than its corresponding pressure would indicate. It is used to get energy out before it starts to condense.

33. The efficiency of the insulation. Increase the amount of insulation plus decrease the pipe size.

34. Increased

35. Increased

36. Decreased

37. Increased

38. 191.08

39. 11.67 cu. ft. of room

Competency:
1. Describe the purpose of hangers and supports in piping systems.
2. Demonstrate the ability to install/fabricate hanger and support setups.

Instructional Objectives:
1. Identify typical hangers, supports, and rod attachments.
2. Explain the function of typical hangers and supports.
3. Differentiate among hangers and supports in terms of their application.
4. Install masonry anchors properly.
5. Install a rod hanger.
6. Fabricate a bracket to given dimensions.

Learning Activities:
1. Read the Pipe Hangers and Supports Information Sheet.
2. Review the "Distance Between Supports Chart" and the formula for determining lengths of structural braces in Pipe Fitting and Piping Handbook, Chapter 15.
3. Examine the hangers and supports on display in your classroom.

Application Exercises:
1. Install masonry anchors properly.
2. Install a rod hanger.
3. Fabricate a bracket to given dimensions.

Evaluation/Checkout:
1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Samples of pipe hangers and supports for classroom display.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. A copy of the information sheet is included with this unit.
2. A copy of the test and answers is included with this unit.
3. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.

Resources:

1. Books:
    - A. Smith, P. and Van Laan, T. Piping and Pipe Support Systems. New York: McGraw-Hill, 1987.
    - B. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. has several publications on pipe supports and hangers. For a publication list contact: Olen Thornton, Executive Director, MSS, 127 Park St., N.E., Vienna, VA 22180, (703) 281-6613.
    - C. Piping Technology and Products, Inc., has a catalog of their products available including pipe hangers and supports. Contact: Piping Technology and Products, Inc., P.O. Box 34506, Houston, TX 77234-4506, (713)643-0038.
    - D. Grinnell Corporation has a catalog of their pipe hangers (Catalog PH87) which would be an excellent reference source. Contact: Grinnell Supply Sales Company, Marketing/Design Services, 155 Westminister Street, Providence, RI 02903, (401) 831-7000.

Pipe Hangers and Supports Information Sheet

Piping is supported to prevent excessive sagging of the pipe, to provide free movement of the pipe due to expansion or contraction, and to prevent the pipe's weight from being carried by the equipment to which it is attached. The support is designed to carry the weight of the pipe, valve, fittings, insulation, and fluid within the pipe (Building Systems Technician, 1986).

The most commonly used support types are weight supports, rigid restraints, snubbers, and sway braces. (Use the pictorial guide at the end of the information sheet as a reference). Weight supports include rod hangers, sliding supports, variable-spring hangers, and constant spring hangers. They are used to resist vertical pipe loads occurring in the downward or gravity direction only. Which one is used is determined by the thermal movement expected to occur at the support location during plant operation (Smith and Van Laan, 1987).

Where vertical thermal movements are minimal, rod hangers may be used. A rod hanger consists of a rod, a rod attachment, and a pipe attachment, such as a pipe ring or clamp. The choice of rod and attachments is determined by load capacities, the need for hanger adjustability, pipe diameter, whether the pipe run is horizontal (clamps or clevis hangers) or vertical (riser clamp), design temperature, and pipe insulation.

In addition to rod hangers, sliding supports may be used where vertical thermal movements are minimal. Sliding supports allow for horizontal thermal pipe movements. The support may be a pipe saddle or a pipe roll. Which support is used depends upon the amount of thermal pipe movement, pipe insulation thickness, and the distance from the pipe to the support steel (Smith and Van Laan, 1987).

Where vertical thermal pipe movements are large, spring hangers are used. Variable-spring supports provide variable supporting forces as the pipe moves vertically. Constant-spring supports are used where the thermal movements (typically over 2 inches) are too large to permit the use of a variable-spring. These supports assure perfectly constant support through the entire deflection or travel of the pipe load (Grinnell, 1987).

Where thermal movements are minimal or where it is necessary to resist weight loads, rigid restraints are used. They may be rigid struts or rigid frames. Rigid frames may consist of wide-flange beams, back-to-back channels, or tubes of structural steel (Smith and Van Laan, 1987). Rigid struts may be attached to the pipe through clamps or welded attachments. Two other types of rigid restraint are the U-bolt and pipe straps.

When the pipe has a high operating temperature, a rigid restraint, most likely, cannot be used. Snubbers or shocks and sway suppressors are then utilized. They may be used in a way similar to the use of springs when thermal movement prevents the use of a rigid hanger (Smith and Van Laan, 1987). Snubbers allow for unrestrained thermal movement but movement is restrained during impulsive or cyclic disturbance (Grinnell, 1987). Weight support is not a feature of a snubber. It is meant as a shock or sway suppressor.

Sway braces are recommended for controlling vibration, absorbing shock loading, guiding or restraining the movement of pipe resulting from thermal expansion, and bracing a pipe line against sway.

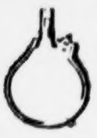
A variety of hangers and supports are available in order to control or restrain pipe movement. As described above, the type most appropriate for the job is determined by a number of factors. Installation is accomplished by the use of structural attachments such as welding lugs, washer plates, brace fittings, brackets and trapeze assemblies.

References:

1. Building System Technician - Course 1. Calgary, Alberta: Southern Alberta Institute of Technology, 1986.
2. Grinnell Pipe Hangers (Catalog PH87). Providence, Rhode Island: Grinnell Corporation, 1987.
3. Smith, P. and Van Laan, T. Piping and Pipe Support Systems. New York: Mc-Graw-Hill, 1987.

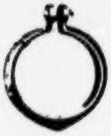
pictorial guide

pipe rings • clamps



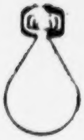
adj. swivel ring
split ring type
fig. 104
¾ to 8 in. pipe

page ph-7



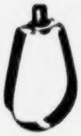
split ring
fig. 108
⅜ to 8 in. pipe
fig. CT-109 ½ to
4 in. copper tubing

pages ph-8, 88 ●



adj. ringe
fig. 97
½ to 8 in. pipe
fig. CT-99
½ to 4 in. tubing

pages ph-9, 87 ●



adj. swivel ring
fig. 70
tapped per NFPA stds.
fig. 69
½ to 8 in. pipe

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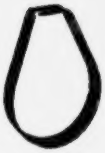
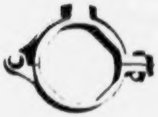


adj. ring
fig. 269
½ to 8 in. pipe

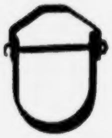
pages ph-11, 89 ●



extension split clamp
fig. 138
⅜ to 3 in. pipe
fig. CT-122 R
½ to 2 in. tubing

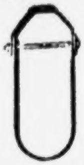
pages ph-8, 88 ●

clevises • clamps



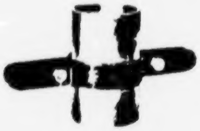
adj. clevis fig. 260
½ to 30 in. pipe
light weight clevis
fig. 65. ⅜ to 4 in. pipe
adj. clevis for C.I. pipe
fig. 590, 4 to 24 in. pipe

pages, ph-11, 12, 23, 89 ●



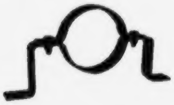
adj. clevis
for insulated lines
fig. 300, 300A alloy
¾ to 12 in. pipe

page ph-13



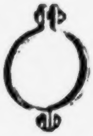
extension pipe or
riser clampe
fig. 261
¾ to 20 in. pipe
fig. CT-121
½ to 4 in. copper tubing

pages ph-14, 90 ●



offset pipe
clamp
fig. 103
½ to 12" pipe

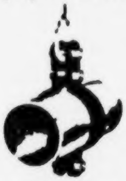
page ph-15



pipe clamp
medium fig. 212
½ to 30 in. pipe
heavy fig. 216
3 to 42 in. pipe

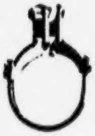
pages ph-19, 20

pipe clamps



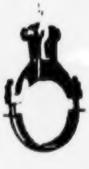
double-bolt pipe clamp
fig. 295, ¾ to 36 in.
fig. 295A, alloy,
1½ to 10 in.
fig. 295H, heavy duty
6 to 36 in.

pages ph-16, 17, 18



alloy pipe
clamp
fig. 224
4 to 16 in. pipe

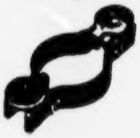
page ph-21



heavy-duty
alloy pipe clamp
fig. 246
10 to 24 in. pipe

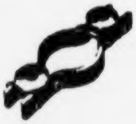
page ph-22

socket clamps



socket clamp
fig. 600
4 to 24 in. pipe

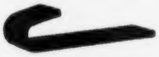
page ph-23



socket clamp
fig. 595
4 to 24 in. pipe

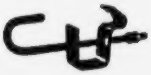
page ph-24

beam clamps



top beam
clamp
fig. 6
⅜ to ⅞ rod

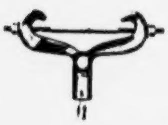
page ph-31



adjustable
beam clamp
fig. 14
⅜ to ⅝ rod

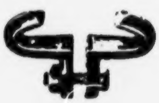
page ph-33

beam clamps (cont'd)



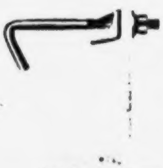
malleable beam clamp
with extension piece
fig. 229; without, fig. 218
safe load: 610 to 1365 lb.

page ph-27



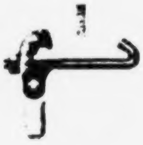
I-beam clamp
fig. 131
safe load: 370 lb.

page ph-29



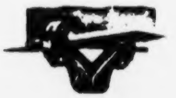
top beam clamp
fig. 227
safe load:
940 lb.

page ph-29



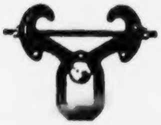
Universal side I-beam
clamp fig. 225. Universal
channel clamp fig. 226
when used with heel plate.
safe load: 390 to 1140 lb.

page ph-28



UFS beam clamp
with UFS nut
fig. 228
safe loads:
up to 11,500 lb.

page ph-35



UFS beam clamp
with weldless eye
nut fig. 292
safe loads:
up to 11,500 lb.

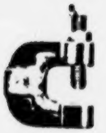
page ph-34

(Courtesy of Grinnell Corporation)

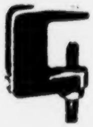
●For copper tubing.
●Also available plastic coated

pictorial guide

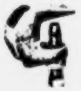
C-clamps • structural attachments

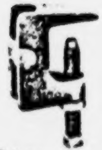

C-clamp
figs. 86, 87, 88
⅜ to ¾ in. rod

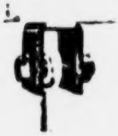
pages ph-30, 91 ●


wide throat
top beam C-clamp
fig. 61
⅜ to ¾ in. rod

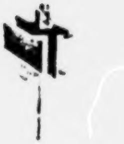
page ph-30


C-type
clamp
top & bottom
beam
fig. 92
std. throat
⅜ and ½" rod
page ph-32


C-type
clamp
top & bottom
beam
fig. 93 wide
throat
⅜ and ½ rod
page ph-32

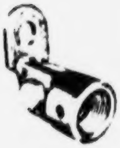

welded
beam attachment
fig. 66
⅜ to 3½ in. rod

page ph-36

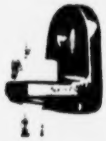

steel washer plate
fig. 60
⅜ to 3¾ in. rod

page ph-39

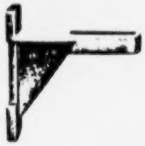
brackets • trapeze assembly


brace fitting
fig. 112, complete
fig. 113, pipe end only
1 & 1¼ in. IPS

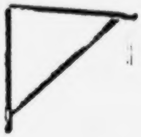
page ph-39


side beam
bracket
fig. 202
max load: 3770 lb.

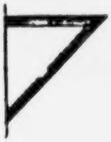
page ph-40


cast iron
bracket
fig. 213
load: 180 lb.

page ph-40


light welded
steel bracket
fig. 194
max load: 750 lb.
clip fig. 193

page ph-41

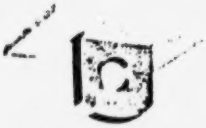

welded steel brackets
medium fig. 195
max load 1500 lb.;
heavy fig. 199
max load: 3000 lb.

page ph-41, 42

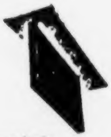
Universal trapeze
assembly fig. 46
safe load to
40,000 lbs.

page ph-43

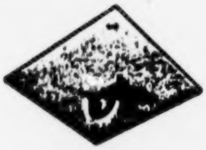
structural attachments • concrete attachments


structural welding lug
fig. 55
½ to 3¾ in. rod (short)
½ to 2 in. rod (long)

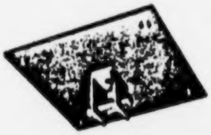
page ph-38


two hole
welding lug
fig. 54
½ to 2¼ in. rod

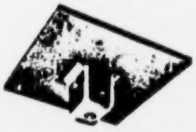
page ph-37


concrete single lug plate
fig. 47
½ to 2 in. rod

page ph-49

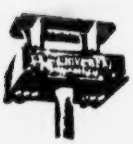

concrete clevis plate
fig. 49
⅜ to 2 in. rod

page ph-50

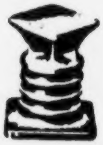

concrete rod
attachment plate
fig. 52
⅜ to 2 in. rod

page ph-51

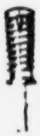
concrete inserts


CB-Universal
concrete insert
fig. 282
⅜ to ⅞ in. rod

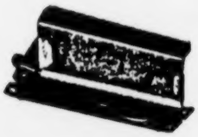
page ph-48


screw
concrete insert
fig. 152
⅜ to ⅞ in. rod

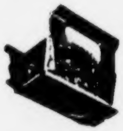
page ph-45


expansion case
closed back type
fig. 117
¼ to ½ in. rod

page ph-45


light weight steel
concrete insert
fig. 285
¼ to ⅝ in. rod

page ph-46


wedge type
concrete insert
fig. 281
¼ to ⅞ in. rod

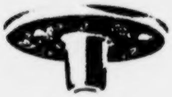
page ph-47

● For copper tubing.

(Courtesy of Grinnell Corporation)

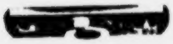
BEST COPY AVAILABLE

ceiling flanges • ceiling plates



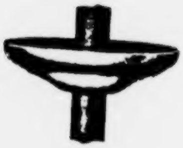
pipe hanger
flange
fig. 153
for ⅜ to ¾ in. rod

page ph-52



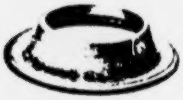
ceiling flange
pipe threaded fig. 128
⅛ to ¾ in. IPS;
rod threaded fig. 128R
⅜ and ½ in. rod

pages ph-52, 91 ●



ceiling plate
fig. 127
⅜ to ½ in. rod

page ph-53



ceiling plate
fig. 395
½ to 8 in. pipe

page ph-53

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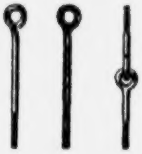
rods • bolts

hanger rods
machine threaded
both ends;
continuous thread

page ph-54

coach screw rods:
other end
machine threaded

page ph-54

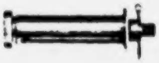


eye rods:
not welded
welded
linked

page ph-55

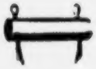
rod with
eye end
fig. 148
2¾ to 5 in.

page ph-56



tapered
load pin
fig. 312
⅜ to 2 in.

page ph-148



clevis pin
w/cotters
fig. 291
½ to 4 in.

page ph-56

bolts:
machine with nut

page ph-57

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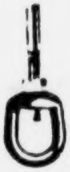
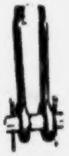
rod attachments



weldless
eye nut
fig. 290
⅜ to
2½ in. rod

page ph-62



forged steel
clevis
fig. 299
⅜ to
4 in. rod

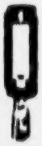
page ph-59

forged steel
turnbuckle
fig. 230
⅜ to 2½ in. rod

page ph-60

carbon steel
turnbuckle
fig. 233
1¼ to 5 in. rod

page ph-60



turnbuckle
adjuster
fig. 114
¼ to
¾ in. rod

pages ph-62, 91 ●

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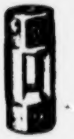
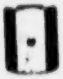
rod attachments



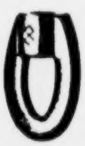
rod
coupling
fig. 136
¼ to
1 in. rod

page ph-61



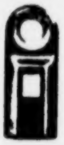
rod coupling
fig. 135
½ to 5 in. rod

page ph-61



socket
rod thr'd fig. 110R
¼ to ⅞ in. rod

pages ph-63, 91 ●

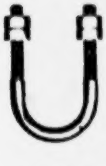


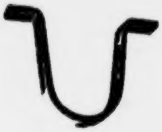
extension piece
fig. 157
⅜ to ⅞ in. rod

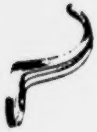
page ph-63

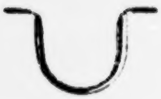
● For copper tubing.

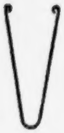
U-bolts • straps • hooks


st'd U-bolt▪ fig. 137
½ to 36 in. pipe;
light-weight U-bolt
fig. 120
½ to 10 in. pipe
pages ph-57, 58

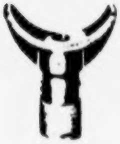

strap
short fig. 262
½ to 4 in. pipe
page ph-64

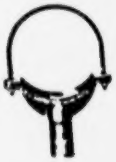

one hole clamp
fig. 126
⅜ to 4 in. pipe
page ph-64

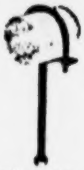

tin strap
fig. 231
¼ to 2 in. pipe
page ph-64

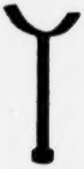

U-hook
fig. 205
¾ to 2 in. pipe
page ph-65

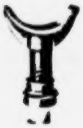
pipe saddles • protection saddle

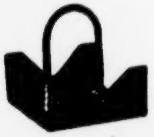

pipe saddle
support
fig. 258
4 to 12 in. pipe
page ph-65

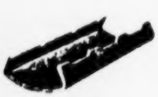

pipe stancheon
saddle
fig. 259
4 to 12 in. pipe
page ph-66

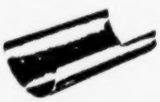

adjustable
pipe stanchion
saddle w/
U-bolt
fig. 191
2 to 12 in. pipe
page ph-67


adjustable
pipe saddle
support
fig. 192
2 to 12 in. pipe
page ph-67

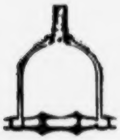

adjustable pipe
saddle support
fig. 264
2½ to 36 in. pipe
page ph-66

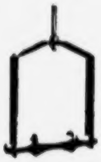

anchor
chair
fig. 198
½ to 24 in. pipe
page ph-68

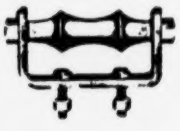

pipe covering
protection
saddle
fig. 160
page ph-69

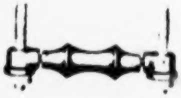

insulation
protection
shield
fig. 167
page ph-72

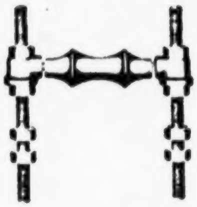
pipe rolls


adj. swivel
pipe roll
fig. 174
2½ to 12 in. pipe
page ph-77

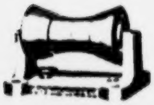

adj. steel yoke
pipe roll
fig. 181
2½ to 20 in. pipe
page ph-76

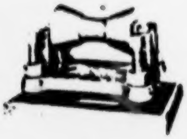

roller chair
fig. 175
2 to 12 in. pipe
page ph-77

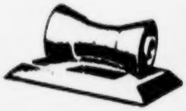

single pipe roll
fig. 171
1 to 30 in. pipe
page ph-73

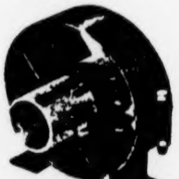

adjustable pipe
roll support
fig. 177
1 to 30 in. pipe
page ph-73

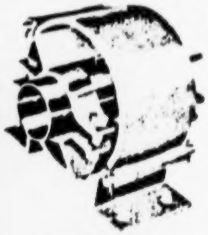
pipe rolls • pipe alignment guides • pipe slides

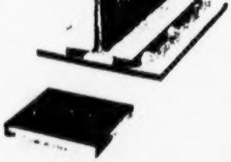

pipe roll stand
complete
fig. 271
2 to 42 in. pipe
page ph-78


adjustable pipe roll
with base fig. 274;
without base fig. 275
2 to 30 in. pipe
page ph-79


pipe roll and plate
fig. 277
2 to 24 in. pipe
page ph-80


pipe
alignment
guide
fig. 255
1 to 24 in. pipe
page ph-81


pipe alignment guide
fig. 256
3 to 24 in. pipe
page ph-83

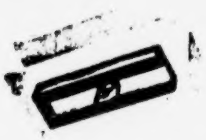

pipe slide assembly
fig. 257
through 24 in. pipe
page ph-85

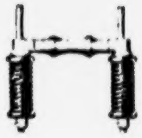
● For copper tubing.
▪Also available plastic coated.

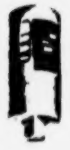
(Courtesy of Grinnell Corporation)

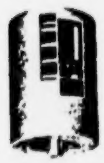
pictorial guide

travelers • spring hangers


horizontal
traveler
fig. 170
page ph-134


spring cushion
for pipe rolls
fig. 178
page ph-75


light duty
spring hanger
fig 247
page ph-92


Pre-Engineered
spring hanger
figs. 82, 98, B-268
page ph-93

Pre-Engineered
spring hanger
figs. C-82, C-98, C-268
page ph-93

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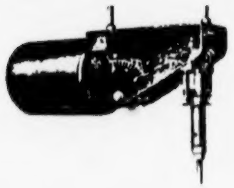
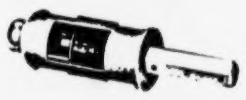
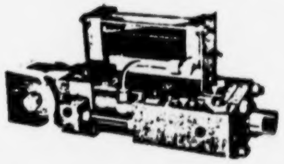
constant supports • sway braces • sway strut assembly • shock suppressors


Constant Support hanger
load: 27 to 87500 lb.
horizontal: fig. 81-H
page ph-111

Constant support hanger
load: 114 to 87500 lb.
vertical; fig. 80-V
page ph-111


vibration control
and sway brace
figs. 296, 301
page ph-135


hydraulic shock and
sway suppressor
fig. 200
page ph-144

(Courtesy of Grinnell Corporation)

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Pipe Hangers and Supports Test

1. List three reasons why piping needs to be supported.

2. List the four commonly used support types.

3. What type of pipe support would you use if you wanted to resist vertical pipe loads occurring in the downward or gravity direction only?

4. What are three components of a rod hanger?

5. What type of rod attachment would you use if you needed a great degree of hanger adjustability?

6. What type of pipe attachment would you use with a rod hanger if the pipe run is vertical?

7. What type of movement do sliding supports allow for?

8. Name two types of sliding supports.

9. When vertical thermal pipe movements are large, what type of weight support should be used?

10. When are rigid restraints used?

11. What are two ways rigid struts may be attached to the pipe?

12. Explain what a snubber is.

13. Name three reasons why sway braces are used.

14. List three structural attachments.

15. Why would a constant-spring support be used rather than a variable spring-support?

Identify each hanger or support your instructor shows you.

16.

17.

18.

19.

20.

21. What is the maximum distance between supports for a 8" standard pipeline assuming a pitch or average gradient of 1" in 15 feet?

22. What is the maximum distance between supports for a 6" standard pipeline assuming a pitch or average gradient of 1" in 30 feet?

23. Determine the necessary dimensions for a three-piece 30 degree x 60 degree angle iron bracket if dimension A is 20 inches and the width of the angle iron is 2 inches. (See page 128-129 in The Pipe Fitter's and Pipe Welder's Handbook).

24. Determine the dimensions for a three-piece 45 degree angle iron bracket, if dimension A is 18 inches and the width of the angle iron is 4 inches. (See page 130-131 in The Pipe Fitter's and Pipe Welder's Handbook).

Pipe Hangers and Supports Test Answers

1. To prevent excessive sagging of the pipe, to provide free movement of the pipe due to expansion or contraction, and to prevent the pipe's weight from being carried by the equipment to which it is attached.
2. Weight supports, rigid restraints, snubbers, and sway braces.
3. Weight support.
4. Rod, rod attachment, and pipe attachment.
5. Turnbuckle.
6. Riser clamp.
7. Horizontal thermal pipe movement.
8. Pipe saddle or a pipe roll.
9. Spring supports.
10. When thermal movement is minimal or when it is necessary to resist weight loads.
11. Clamps or welded attachments.
12. Snubbers or shock and sway suppressors allow for unrestrained thermal movement but movement is restrained during impulsive or cyclical disturbance.
13. Controlling vibration, absorbing shock loading, guiding or restraining the movement of pipe resulting from thermal expansion, and bracing a pipe line against sway.
14. Welding lugs, washer plates, brace fittings, brackets, and trapeze assemblies.
15. When the thermal movements are too large to permit the use of a variable-spring.

16. - 20.

21. 41 feet

22. 28 feet

23. A = 20 inches, B = 34.64 inches, C = 40 inches, D = 2 inches, E = 7.464 inches, F = 3.464 inches.

24. A = 18 inches, B = 18 inches, C = 25.45 inches, D = 4 inches, E = 9.65 inches, F = 9.65 inches.

To the Instructor: The following Modules on pipe welding are meant to provide the apprentice with a general exposure to the pipe welding field. Even if the apprentice has no prior knowledge and/or skills in welding, the majority of the material will be understandable and beneficial to the apprentice.

If the apprentice has no prior knowledge and/or skill in welding, all of Modules I and II should be used and Instructional Objectives 1-6 in Module III should be used. The remainder of Module III is devoted to pipe welding technique and actual pipe welding and assumes knowledge and skill in shielded metal arc welding. If this skill is present, all of Module III should be used by the apprentice. For the apprentice without the necessary prior welding skill, the Welding-Basic Skills Module should be used.

One final note, as was mentioned in the beginning, these Modules are meant to present a general exposure to welding. To develop skill in welding, a great deal of practice is necessary, more so in pipe welding. Apprentices should supplement welding skills covered in the curriculum with courses (on their own) which are appropriate for their particular job duties.

Competency:

1. Differentiate between categories of pipe welding.
2. Identify pipe welding qualification positions.
3. Describe safety requirements for pipe welding.
4. Describe equipment required for pipe welding setup.
5. Demonstrate the ability to use welding setup equipment.

Instructional Objectives:

1. Match terms related to pipe welding orientation, safety, and equipment with their correct definitions.
2. Differentiate between basic categories of pipe welding.
3. Complete a list of characteristics of industrial pipe welding.
4. Solve problems concerning classifications for industrial pipe.
5. Complete statements concerning welding skills required for good pipe welding.
6. Differentiate between organizations that set pipe and pipe welding standards.
7. Identify AWS test positions for groove welds on pipe.
8. Complete statements concerning how pipe welders are qualified.
9. Identify true statements concerning general guidelines for pipe welding safety.
10. Complete statements concerning types of line-up clamps and their characteristics.
11. Select true statements concerning characteristics of pipe beveling machines.
12. Complete statements concerning jack stands and their uses.
13. Select true statements concerning center finders and their uses.
14. Differentiate between types of contour markers.
15. Solve a problem concerning wrap-arounds and their uses.
16. Complete statements concerning templates and their uses.
17. Complete statements concerning the use of two-hole pins and back-up rings.
18. Demonstrate the use of internal and external line-up clamps.
19. Demonstrate the use of center finders and contour markers.
20. Demonstrate the use of a wrap-around.
21. Demonstrate the use of two-hole pins.
22. Demonstrate the use of back-up rings.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet in Unit I "Pipe Welding Orientation, Safety, and Equipment" of "Shielded Metal Arc Pipe Welding."
2. Read Chapter 12 in Pipe Fitting and Piping Handbook.
3. Examine the various types of welded pipe and pipe welds on display in your classroom.
4. View the videotape on the Dearman System dealing with pipe fit-up tools for welding.

5. Observe as your instructor or a company representative demonstrates the procedure for using the Dearman System of tools for welding. Use the Dearman System Handbook as your guide.
6. Observe as your instructor or a company representative demonstrates the procedure for using the Contour Precision Layout and Measuring Tools from Jackson Products. Use the Contour Marker instruction booklet as your guide.

Application Exercises:
1. Demonstrate the use of internal and external line-up clamps.
2. Demonstrate the use of center finders and contour markers.
3. Demonstrate the use of a wrap-around.
4. Demonstrate the use of two-hole pins.
5. Demonstrate the use of back-up rings.

Evaluation/Checkout:
1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Examples of various types of welded pipe and pipe welds for classroom display.
2. Equipment necessary to demonstrate the Dearman System of pipe fit-up tools for welding. The Dearman System Catalog, Handbook, videotape, and a demonstration kit is available from: Donald Aycock, Dearman Product Manager, Dearman System, A Division of Cogsdill Tool Products, Inc., P.O. Box 900, Camden, SC 29020, (800)231-6678, (803)438-4000. A demonstration kit is available at reduced cost (25% discount) to educational institutions. The kit contains the following equipment: 1 - 8" Double Screw Chain Clamp, Mini-Fit Light Duty Clamp, Elliptical Hole Marker, Contour Marker, Pipefitters Square, Hold Down Clamp, 2 Hole Leveler, Hi-Lo Gauge, and a Demonstration Videotape. To arrange for a company representative to provide a demonstration contact: Contractors Supply and Equipment, Inc., 401 N. Perkins St., P.O. Box 1173, Appleton, WI 54912-1173, (414)739-2607. Ask them to arrange for the Dearman System van to visit the school. Contractor's Supply and Equipment, Inc., is the authorized distributor for the Dearman System tools for the state of Wisconsin.
3. Equipment necessary to demonstrate contour markers, layout tools, and measuring tools. The Contour Precision Layout and Measuring Tools Catalog, Contour Marker Instruction Booklet, and Jackson Protective Products and Welding Accessories Catalog is available from: Helen P. Basso, Marketing Coordinator, Contour Sales, A Division of Jackson Products, 5801 Safety Drive N.E., Belmont, MI 49306, (800)253-7281, (616)784-6200. To arrange for a company representative to provide a demonstration contact: Dave Dockstader Zone Manager, (312)553-6005. Jackson Products offers a 10% discount to educational institutions through their distributors. Contact the company for the name of the nearest distributor.

4. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Fortney, C. and Gregory, M. Shielded Metal Arc Pipe Welding. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (600701) and a student manual (600702) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
2. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
3. The test and answers are included with the instructor's guide for Shielded Metal Arc Pipe Welding. The test contains questions about cross-country pipe welding. These should be deleted from the test. They are questions 4 and 13.

Audio-Visual Materials:

1. The videotape on the Dearman System is available from Cogsdill Tool Products, Inc. The address is given above.

Resources:

1. Books
   - A. Sosnin, H.A. Procedures for Pipewelding. Washington, D.C.: National Association of Plumbing, Heating, and Cooling Contractors, 1981. An excellent reference describing the different methods of welding pipe. Twenty individual welding procedures are explained, in detail, with accompanying illustrations.
   - B. Graham, E. Maintenance Welding. Englewood Cliffs, New Jersey: Prentice-Hall, 1985.
   - C. Safety in Welding and Cutting. Miami, Florida: American Welding Society, 1983.
   - D. Stewart, J. Welding Troubleshooting Guide. Reston, Virginia: Reston Publishing Company, 1983.
   - E. Connor, L. Welding Handbook, 8th Ed. Miami, Florida: American Welding Society, 1987.
   - F. Smith, D. Welding Skills and Technology. New York: Mc-Graw-Hill, 1984.
   - G. Sacks, R. Essentials of Welding. Mission Hill, California: Glencoe Publishing Company, 1984.
   - H. Althouse, A., Turnquist, C., Bowditch, W., and Bowditch, K. Modern Welding. South Holland, Illinois: Goodheart-Willcox, 1984.
   - I. Jeffus, L. and Johnson, H. Welding: Principles and Applications, 2nd Ed. Albany, New York: Delmar, 1989.

J. Giachino, J. and Weeks, W. Welding Skills. Homewood, Illnois: American Technical Publishers, 1985.
K. Brumbaugh, J. Welders Guide. Indianapolis, Indiana: Audel, 1983.
L. Stewart, J. Welders/Fitters Guide. Indianapolis, Indiana: Audel, 1979.
M. Rampaul, H. Pipe Welding Procedures. New York: Industrial Press, 1973.
N. Cary, H. Modern Welding Technology, 2nd Ed. Englewood Cliffs, New Jersey: Prentice-Hall, 1989.
O. Koellhoffer, L., Manz, A., and Hornberger, E. Welding Processes and Practices. New York: Wiley, 1988.
P. Stincomb, C. Welding Technology Today. Englewood Cliffs, New Jersey: Prentice-Hall, 1989.
Q. Specifications for Qualifications of Welding Procedures and Welders for Piping and Tubing. Miami, Florida: American Welding Society, 1981.
R. Kennedy, G. Welding Technology. Mission Hills, California: Glencoe Publishing Company, 1985.
S. Scheck, L. and Edmondson, G. Practical Welding, 2nd Ed. Mission Hills, California: Glencoe Publishing Company, 1988.
T. Hull Maintenance Technician 3 & 2, Vol. 1. (Naval Education and Training Command - NAVEDTRA 10571). Washington, D.C.: United States Government Printing Office, 1984. (Stock Ordering No. 0502-LP-052-8630)
U. Griffin, I., Roden, E., and Briggs, C. Basic Oxyacetylene Welding, 4th Ed. Albany, New York: Delmar, 1986.
V. Griffin, I., Roden, E., and Briggs, C. Basic TIG & MIG Welding, 3rd Ed. Albany, New York: Delmar, 1986.
W. Griffin, I., Roden, E., and Briggs, C. Basic Arc Welding, 4th Ed. Albany, New York: Delmar, 1986.
X. Jeffus, L. Safety for Welders. Albany, New York: Delmar, 1982.
Y. Griffin, I., Roden, E.M., Jeffus, L., and Briggs, C.W. Welding Processes, 3rd Ed. Albany, New York: Delmar, 1986.
Z. Jeffus, L., Griffin, I., Roden, E.M., and Briggs, C.W. Pipe Welding Techniques, 4th Ed. Albany, New York: Delmar, 1987.
AA. Smith, D. Welding Skills and Technology. New York: McGraw-Hill, 1984.
BB. Mohler, R. Practical Welding Technology. New York: Industrial Press, 1983.
CC. Welding Electrodes Identification and Welding Equipment Safety and Operations. Athens, Georgia: American Association for Vocational Instructional Materials, 1984. (Both of these are computer software programs).
DD. Arc Welding. Athens, Georgia: American Association for Vocational Instructional Materials, 1984.
EE. Introduction to Welding. Oxyacetylene Welding and Cutting, Shielded Metal Arc Welding, Gas Tungsten Arc Welding, Gas Metal Arc Welding/Flux-Cored Arc Welding, and Blueprint Reading and Layout for Welding. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. These are competency based curriculums with instructor guides and student manuals.

2. Audio-Visual Material:
   A. Hobart School of Welding Technology has numerous videotapes and training materials available. For a catalog contact: Hobart Brothers Company, Box DM-602, Troy, OH 45373, (800) 424-1544.
   B. Lincoln Electrical Company has several videotapes and films available. Contact: Richard D. Smith, Public Relations Coordinator, The Lincoln Electric Company, 22801 St. Clair Ave., Cleveland, OH 44117-1199, (216)481-8100.
   C. Miller Electric has numerous videotapes available including complete courses with student textbooks and instructor's manuals on "Shielded Metal Arc Plate Welding," "Shielded Metal Arc Pipewelding," and "Gas Metal Arc Plate Welding." Contact: Mike Pankratz, Technical Support Specialist, Miller Electric Manufacturing Company, 1635 W. Spencer Street, P.O. Box 1079, Appleton, WI 54912, (414)734-9821.
   D. "Pipe Welding" is a six part slide/tape presentation with study guide and tests available from Bergwall Productions, Uniondale, NY 11553. They also have produced a videotape series on MIG Welding and TIG Welding.
   E. "Introduction to Arc Welding," "Introduction to Gas Welding," "Non-Destructive Testing," and "Practical Shop Metallurgy" are videotapes available from NUS Training Corporation.
   F. "Oxyacetylene Cutting" is videotape available from Marshall Maintenance Productions.
   G. "Welding Test and Inspection" is a videotape series available from L & K International Videotraining.
   H. "Welding - MIG and TIG Welding - A Series," "Welding - Oxy-Acetylene Welding - A Series," and "Welding - Shielded Metal-Arc Welding - A Series" are videotapes available from ICS-Intext, 315 Post Road West, Westport, CT 06880, (203)227-0891.
   I. "Welding I - Basic Oxy-Acetylene Welding - A Series," "Welding II - Basic Shielded Metal Arc Welding - A Series," and "Welding III - TIG and MIG Welding - A Series," are videotapes available from Cambridge The Adult Education Company, 800 Seventh Ave., New York, NY 10016, (800)221-4600, (800)221-4764.
   J. "Electric Arc Welding" and "Advanced Welding" are a series of videotapes available from Tel-A-Train, Inc. The "Advanced Welding" series includes tapes on welding carbon steel pipe, low alloy pipe, and stainless steel pipe.
   K. "Safety and Health Factors in Welding and Cutting" and "Hazards of Gas Welding" are slide/tape presentations available from National Audio Visual Center, 8700 Edgeworth Drive, Capitol Heights, MD 20743-3701.
   L. "Welding Steel" and "Welding Pipe" are videotapes available from Gulf Publishing Company - Video Publishing, P.O. Box 2608, Houston, TX 77252-2608, (713)529-4301.

M. "Welding Trades Series" is a three-part videotape series available from Video Training Resource, Inc. A workbook is included for each part of the series. The three parts are: oxyacetylene welding, shielded metal arc welding, MIG and TIG welding.

N. "The Welding Test and Inspection Series" is a videotape series available from Video Training Resources, Inc. A workbook is included with the series.

O. "The Pipe Welding Series" is a videotape series available from Video Training Resources, Inc. A workbook is included with the series. The series covers joint design and preparation, carbon steel pipe welding, aluminum pipe welding, and alloyed steel pipe welding.

P. "Welding Series" are videotapes available from Industrial Training Corporation. Each tape includes a workbook, facilitator's guide, and overhead transparency set. There are two tapes on pipe welding, one on shielded metal arc and one on TIG welding.

Q. Lakeshore Technical College has a welding program consisting of 17 videotapes. Oxyacetylene, arc, and gas metal arc welding are covered. Contact: Charles Ma, Media Specialist, Lakeshore Technical College, 1290 North Avenue, Cleveland, WI 53015, (414) 458-4183.

3. Pamphlets:

A. "Pipe Fitters Manual" is available from Tube Turns, Inc., P.O. Box 32160, Louisville, KY 40232, Attn: Marketing Services Dept.

B. American Welding Society has numerous publications available. Their address is: 550 N.W. Le Jeune Road, P.O. Box 351040, Miami, FL 33135.

C. Miller Electric has numerous publications and training aids available including guides on various welding processes, a troubleshooting guide, and an equipment catalog. Contact: Mike Pankratz, Technical Support Specialist, Miller Electric Manufacturing Company, 1635 W. Spencer Street, P.O. Box 1079, Appleton, WI 54912, (414)734-9821.

D. The Lincoln Electric Company has numerous publications and training aids available including:

1) Procedure Handbook
2) E201 Safety Poster
3) M629 Storing and Redrying Manual Electrodes
4) M210 Mild Steel Weld Directory
5) M212 Stainless Steel Welding Directory
6) M640 Welding Pressure Pipelines and Piping Systems
7) ED68.1 Welding Tips and Electrode Selection Chart
8) ED89 Pipe Welding Charts
9) GS100 Gas Metal Arc Welding Technical Manual

Contact: Richard D. Smith, Public Relations Coordinator, The Lincoln Electric Company, 22801 St. Claire Ave., Cleveland, OH 44117-1199, (212)481-8100.

Competency:

1. Discuss the use of pipe symbols in blueprint reading and layout for pipe welding.
2. Identify symbols for pipe and pipe fittings.
3. Describe the advantages of using isometric drawings for pipe welding blueprints.
4. Solve basic layout problems.
5. Construct templates for pipe welding applications.

Instructional Objectives:

1. Match terms related to blueprint reading and layout for pipe welding with their correct definitions.
2. Identify methods for presenting pipe on blueprints.
3. Match common piping symbols with their meanings.
4. Identify methods for dimensioning blueprints for pipe welding.
5. Identify symbols for common pipe fittings.
6. Match special welded fittings with their uses.
7. Identify statements concerning advantages of isometric drawings for pipe welding blueprints.
8. Identify statements concerning steps in solving trigonometric problems.
9. Arrange in order the steps in laying out angles on 90 degree long radius elbows.
10. Solve a problem using the 12-inch rule for finding angles with a steel square.
11. Complete a statement concerning pipe identification.
12. Complete a list of standard weld fittings.
13. Solve trigonometry problems for unknown sides and unknown angles.
14. Demonstrate the ability to develop a template for an orange-peel head on 2" pipe.
15. Demonstrate the ability to develop a template for a two-piece 90 degree turn.
16. Demonstrate the ability to develop a template for a 90 degree branch with pipes of equal size.
17. Demonstrate the ability to develop a template for a 45 degree branch connection.

Learning Activities:

1. Read and then discuss in-class sessions the Information Sheet in Unit II "Blueprint Reading and Layout for Pipe Welding" of Shielded Metal Arc Pipe Welding.
2. Attend an in class presentation by a layout specialist from a welding company.
3. Complete Assignment Sheet 1, "Solve Trigonometry Problems for Unknown Sides" in Unit II of Shielded Metal Arc Pipe Welding.

4. Complete Assignment Sheet 2, "Solve Trigonometry Problems for Unknown Angles" in Unit II of Shielded Metal Arc Pipe Welding.
5. Complete Job Sheet 1, "Develop a Template for an Orange-Peel Head on 2" Pipe" in Unit II of Shielded Metal Arc Pipe Welding.
6. Complete Job Sheet 2, "Develop a Template for a Two-Piece 90 Degree Turn" in Unit II of Shielded Metal Arc Pipe Welding.
7. Complete Job Sheet 3, "Develop a Template for a 90 Degree Branch with Pipes of Equal Size" in Unit II of Shielded Metal Arc Pipe Welding.
8. Complete Job Sheet 4, "Develop a Template for a 45 Degree Branch Connection" in Unit II of Shielded Metal Arc Pipe Welding.

Evaluation/Checkout:

1. Submit Assignment Sheets 1 and 2.
2. Submit Job Sheets 1, 2, 3, and 4.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Materials necessary to complete each Job Sheet. A list of Tools and Materials is at the beginning of each Job Sheet.

Learning Materials:

Note: Most of this module should be review for the apprentice. The material was presented previously in the Math, Pipe Drafting, and Template Development Modules.

1. Fortney, C. and Gregory, M. Shielded Metal Arc Pipe Welding. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (600701) and a student manual (600702) are available, Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
2. Contact a local welding shop and arrange to have a layout specialist talk to the class about the special tools and skills required to produce accurate layouts.

Resources:

1. A listing of books, audio-visual material, and pamphlets is detailed in Pipe Welding I.
2. In the instructor's guide for Shielded Metal Arc Pipe Welding, suggested supplemental materials are listed for each unit.

Competency:

1. Identify proper electrodes for pipe welding.
2. Describe joint preparation, fit-up, alignment, and cleaning requirements for pipe welding.
3. Explain methods of nondestructive and destructive weld testing.
4. Demonstrate the ability to bevel and prepare pipe for welding.
5. Conduct destructive tests on welded pipe.
6. Weld to specifications V-groove joints in vertical up and vertical down positions.

Instructional Objectives:

1. Match terms related to pipe welding techniques and applications with their correct definitions.
2. Select true statements concerning guidelines for beginning pipe welders.
3. Solve problems concerning AWS electrode classifications for mild steel and alloy electrodes.
4. Complete statements concerning electrode selection for pipe welding.
5. Complete statements concerning joint preparation, fit-up and alignments for pipe welding.
6. Identify common methods of pipe alignment.
7. Complete statements concerning joint preparation for vertical down pipe welding.
8. Complete statements concerning special items in vertical down joint preparation.
9. Identify true statements concerning pass detail and sequence for vertical down pipe welding.
10. Complete statements concerning joint preparation for vertical up welding.
11. Complete statements concerning pass detail and sequence for vertical up pipe welding.
12. Select true statements concerning techniques for horizontal pipe welding.
13. Complete statements concerning cleaning requirements for all pipe welding.
14. Match common problems in pipe welding with their causes.
15. Complete a pipe welding troubleshooting chart.
16. Complete a list of ways to prevent pipe welds from cracking.
17. Solve problems concerning the concept of quartering.
18. Differentiate between methods of pipe inspection.
19. Demonstrate the ability to bevel and prepare pipe for welding.
20. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the horizontal position.
21. Demonstrate the ability to conduct root and face bend tests and a nick-break test on welded pipe.
22. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the vertical up position.

23. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the vertical down position.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet in Unit III "Pipe Welding Techniques and Applications" of Shielded Metal Arc Pipe Welding.
2. View the videotapes "Shielded Metal Arc Pipe Welding" (Miller Electric).
3. Complete Job Sheet 1, "Bevel and Prepare Pipe for Welding" in Unit III of Shielded Metal Arc Pipe Welding.
4. Complete Job Sheet 2, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Horizontal Position" in Unit III of Shielded Metal Arc Pipe Welding.
5. Complete Job Sheet 3, "Conduct Root and Face Bend Tests and a Nick-Break Test on Welded Pipe" in Unit III of Shielded Metal Arc Pipe Welding.
6. Complete Job Sheet 4, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Up Position" in Unit III of Shielded Metal Arc Pipe Welding.
7. Complete Job Sheet 5, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Up Position" in Unit III of Shielded Metal Arc Pipe Welding.
8. Complete Job Sheet 6, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Down Position" in Unit III of Shielded Metal Arc Pipe Welding.
9. Complete Job Sheet 7, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Down Position" in Unit III of Shielded Metal Arc Pipe Welding.

Evaluation/Checkout:

1. Complete Job Sheets 1, 2, 3, 4, 5, 6, and 7.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Materials necessary to complete each Job Sheet. A list of Tools and Materials is at the beginning of each Job Sheet.

Learning Materials:

1. Fortney, C. and Gregory M. Shielded Metal Arc Pipe Welding. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (600701) and a student manual (600702) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.

2. The test and answers is included with the instructor's guide for Shielded Metal Arc Pipe Welding. The test contains questions which asks for information that was not part of the instructional objectives. The following questions should be deleted from the test: 18,20-27.

Audio-Visual Material:

1. The videotape series "Shielded Metal Arc Pipe Welding" is available from Miller Electric Manufacturing Company. The following topics are covered:
    -- Pipe Welding Fundamentals, 2F Position
    -- 2G Position (Without Backing Ring)
    -- 2G Position (With Backing Ring) Weld Defects
    -- 5F Position
    -- 5G Position (Without Backing Ring)
    -- 5G Position (With Backing Ring)
    -- 6G Position
    -- Shielded Metal Arc (Pipe) Specimen Preparation

    The tapes should be shown prior to the appropriate Job Sheet. To order the tapes contact: Mike Pankratz, Technical Support Specialist, Miller Electric Manufacturing Company, 1635 W. Spencer Street, P.O. Box 1079, Appleton, WI 54912, (414)734-9821. The videotapes include one student text and one instructor's manual.

Resources:

1. A listing of books, audio-visual material, and pamphlets is detailed in Pipe Welding I.
2. In the instructor's guide for Shielded Metal Arc Pipe Welding, suggested supplemental materials are listed for each unit.

Competency:

1. Demonstrate the setup, use, and care of oxyacetylene welding-cutting equipment.
2. Demonstrate the setup, use, and care of shielded metal arc welding equipment.

Instructional Objectives:

1. Match terms related to cutting and welding with their correct definitions.
2. Complete a list of equipment required for oxyacetylene welding.
3. Identify the parts of a cutting torch.
4. Complete statements concerning basic safety rules for oxyacetylene cylinders and gases.
5. Match examples of poor cuts with their causes.
6. List causes of a backfire.
7. Complete statements concerning the results of a backfire.
8. Complete statements concerning the results of a flashback.
9. Arrange in order the steps to follow in case of a flashback.
10. Select factors that determine fusion weld quality.
11. List five properties of a good weld.
12. Select factors that determine tip size selection in welding.
13. Select factors that determine filler rod selection in welding.
14. State the purpose of the filler rod.
15. Identify four types of oxyacetylene fusion welding flames.
16. Select the proper tip size, acetylene pressure, and oxygen pressure for a given metal thickness.
17. Select the acceptable lens shade number for welding a given metal thickness.
18. Demonstrate personal protection when welding by wearing the proper safety clothing and equipment.
19. Assemble, inspect, light, adjust, extinguish, turn-off, and disassemble oxyacetylene welding-cutting equipment.
20. Setup shielded metal arc welding equipment selecting the proper electrodes, amperage, voltage, current, and polarity.
21. Make ninety degree cuts on mild steel and restart a cut using oxyacetylene welding equipment.
22. Make a bevel cut on mild steel using oxyacetylene welding equipment.
23. Make a straight and bevel cut on pipe using oxyacetylene welding equipment.
24. Lay beads on metal with and without a filler rod using oxyacetylene welding equipment.
25. Weld a butt joint in the flat position using oxyacetylene welding equipment.
26. Strike an arc and weld stringer and weave beads using shielded metal arc welding equipment.

27. Weld a single V-groove butt joint in the flat position using shielded metal arc welding equipment.
28. Make a tee joint with a fillet weld using shielded metal arc welding equipment.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet from Section E in Unit V-E "Oxyacetylene Cutting, Welding, and Brazing." of Air Conditioning and Refrigeration Fundamentals.
2. Read "Principles of Arc Welding" by Miller Electric.
3. View the videotape "Arc Welding Methods" (Miller Electric).
4. View the videotape series "Shielded Metal Arc Plate Welding - Part I" (Miller Electric).
5. Complete Job Sheet 1, "Setup Oxyacetylene Welding Equipment."
6. Complete Job Sheet 2, "Light, Adjust, and Shut Off Oxyacetylene Welding Equipment."
7. Complete Job Sheet 3, "Make 90 Degree Cuts on Mild Steel and Restart a Cut."
8. Complete Job Sheet 4, "Make a Bevel Cut on Mild Steel."
9. Complete Job Sheet 5, "Make a Straight Cut on Pipe."
10. Complete Job Sheet 6, "Make a Bevel Cut on Pipe."
11. Complete Job Sheet 7, "Lay Beads on Gauge Metal Without a Filler Rod."
12. Complete Job Sheet 8, "Lay Beads on a Flat Plate With a Filler Rod."
13. Complete Job Sheet 9, "Weld a Butt Joint in the Flat Position."
14. Complete Job Sheet 10, "Weld Stringer and Weave Beads."
15. Complete Job Sheet 11, "Weld a Tee Joint."
16. Complete Job Sheet 12, "Weld a Single V-Grooved Butt Joint."

Evaluation/Checkout:

1. Complete Job Sheets 1-12 and have your instructor evaluate your performance. Practice welds will be compared to master welds.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. "Principles of Arc Welding" is available from Miller Electric. Contact: Mike Pankratz, Technical Support Specialist, Miller Electric Manufacturing Company, 1635 W. Spencer Street, P.O. Box 1079, Appleton, WI 54912, (414)734-9821.
2. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. The majority of this manual is used for the Refrigeration and Air Conditioning portion of the curriculum. An instructor's guide (800401), a student manual (800402), and a transparency set (800403) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800)654-3988. The instructor's guide includes performance objectives suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.
3. Job Sheets 1, 2, 3, 7, 8, and 9 are in Air Conditioning and Refrigeration Fundamentals. Job Sheets 4, 5, 6, 10, 11, and 12 are included with this module.

Audio-Visual Material:

1. The videotapes "Arc Welding Methods" and "Shielded Metal Arc Plate Welding - Part I" are available from Miller Electric. The address is given above. The tape "Arc Welding Methods" provides a comprehensive introduction to the arc welding methods most widely used. The major processes presented in this program are: Shielded Metal Arc (stick), Gas Tungsten-Arc (TIG), Resistance Spot, Gas Metal-Arc (MIG), Submerged Arc, Air Carbon-Arc Gouging.

   The "Shielded Metal Arc Plate Welding - Part I" series is designed for beginners. The series includes a student textbook and instructor material. This information could be used in conjunction with this module. The video-tapes cover the following topics:
   -- Welding Equipment and Safety
   -- Striking an Arc and Running a Bead
   -- Weaving the Electrode
   -- Oxyacetylene Equipment and Safety
   -- Oxyacetylene Flame Cutting
   -- Fillet Weld Techniques
   -- Fillet Welds with E7024 Electrodes
   -- Flat Position Vee Butt Joints (This tape is part of the advanced series in Part 2).

   These tapes should be shown prior to the appropriate Job Sheet.

Resources:

1. A listing of books, audio-visual material, and pamphlets is detailed in Pipe Welding I.

Job Sheet 4

Make a Bevel Cut on Mild Steel Plate

Layout and make a guided bevel cut ± 5 degrees from a 45 degree angle on mild steel plate using oxyacetylene welding equipment.

Job Sheet 5
Make a Straight Cut on Pipe

Layout and make a straight cut on 4" diameter pipe using oxyacetylene welding equipment.

Job Sheet 6
Make a Bevel Cut on Pipe

Layout and make a bevel cut on 4" diameter pipe using oxyacetylene welding equipment.

Job Sheet 10
Weld Stringer and Weave Beads

Setup shielded metal arc welding equipment selecting the proper amperage, voltage, current, and polarity to strike an arc and weld stringer and weave beads with E6010 or E6011 electrodes on 1/4" thick mild steel plate.

Job Sheet 11

Weld a Tee Joint

Setup shielded metal arc welding equipment selecting the proper electrode, amperage, voltage, current, and polarity to weld a tee joint with a fillet weld in the flat position on 1/4" thick mild steel plate.

Job Sheet 12

Weld a Single V-Grooved Butt Joint

Setup shielded metal arc welding equipment selecting the proper amperage, voltage, current, and polarity to weld a single V-grooved butt joint in the flat position using multipassed weaved welds with 6010 or 6011 electrodes for the root and 1/8" to 5/32" diameter E7018 electrodes to cover on 1/4" thick mild steel plate.

Competency:
1. Describe the manner in which a force is transmitted through a confined fluid.
2. Explain the operation of transmitting energy in an efficient pneumatic system.
3. Distinguish among the various control devices used in a pneumatic system.

Instructional Objectives:
1. Define Pascal's law.
2. Define pressure.
3. Explain what a fluid power cylinder consists of.
4. Describe how a cylinder works.
5. Describe the operation of an intensifier.
6. Identify two pressure scales used to measure pressure in a fluid power system.
7. Explain how a plunger gauge and a bourdon tube gauge works.
8. Define what a gas is.
9. Define what heat energy is.
10. Explain what gas pressure is.
11. Describe the relationship between volume, temperature, and pressure in a pneumatic system.
12. Describe the operation of a positive displacement compressor.
13. List three causes of pneumatic system inefficiency.
14. Explain how flow rate is measured in a pneumatic system.
15. Explain how the term velocity is used in a pneumatic system.
16. Describe why pressure must be controlled in a pneumatic system.
17. Explain how a pressure switch works in a pneumatic system.
18. Explain how a safety relief valve works in a pneumatic system.
19. Explain how a pressure regulator works in a pneumatic system.
20. Describe the purpose of a double-acting cylinder and a directional control valve in a pneumatic system.
21. Describe how flow rate is controlled in a pneumatic system.
22. Identify pneumatic symbols.

Learning Activities:
1. Read Chapters 1,2,3, and 4 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 2,3,and 4.
3. View the videotapes "Force Transmission Through a Fluid," "Energy Transmission Using a Pneumatic System," and "Control of Pneumatic Energy" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as provided by your instructor.

Evaluation/Checkout:
1. Submit your answers to the Exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
A few of the companies that manufacture Pneumatics Trainers are listed below.

Lab-Volt Systems
5785 Pembroke Drive
Madison, WI 53711
Contact: Mark Hillerns (District Sales Supervisor)
(608)273-1152

Lab Volt has several pneumatics training systems available. The course of study correlates pneumatic theory with student training exercises that cover basic components, practices, and troubleshooting. Principles covered pertain to the control, distribution and utilization of compressed air. Concepts learned are applied to linear actuators, cylinders, rotary acutators, linear air bearings, venturi tubes, valves, and pneumatic test and measurement devices.

The trainers include hardware illustrative of principles being studied, a student laboratory manual, an instructor's guide, a workbench, and an optional air compressor. The workbench has locking casters and clear acrylic locking doors providing safe, yet fully accessible storage for all hardware items. I.S.O. symbols and written descriptions identify the locations of all components in the storage cabinet.

Several components are constructed of clear acrylic permitting students to view the operation of various parts. An overhead transparency projector can be used for group viewing.

The modular design permits arranging course materials to fit varying course objectives. Manuals are written with step-by-step instructions for each exercise, and questions are provided to stimulate problem solving and for immediate evaluation of training progress.

FESTO Corporation
395 Moreland Road
Hauppauge, NY 11788
(516)435-0800

The Festo Learning System combines industrial components, patented learning assemblies and classroom proven courseware to give you everything you need to help students prepare to deal with today's Control and Power Technologies. Coupled with an extensive collection of texts and support materials such as videotapes and multi-colored overhead transparency sets, the system provides a full set of resources to build your teaching capabilities in:

- -- Pneumatics
- -- Electro-Pneumatics
- -- Hydraulics
- -- Electro-Hydraulics
- -- Proportional Hydraulics
- -- Programmable Logic Controllers

The system's modular design allows for exact tailoring to your needs. Hardware: All Festo Didactic training assemblies start with actual industrial components. Each assembly includes the component, information such as circuit diagrams and industrial symbols, and prefitted connections, filters, etc. The patented Festo hardware system makes assembling power and control circuits easy, and so the student can focus on learning.

Courseware: Each Learning System module is based on hands-on exercises. The student learns a concept, and applies it in a real situation. Courseware is keyed to the hardware sets in the system and all modules are compatible. That means you can gear the program directly to your curriculum requirements.

Hampden Engineering Corporation
P.O. Box 563
East Longmeadow, MA 01028-0563
Contact: Sheldon Shattuck
(413)525-3981

The Hampden H-FP/BP Basic Pneumatics segment of the Hampden Fluid Power Learning System consists of a control panel, a selection of pneumatic components, and a student manual. The Pneumatics Control Panel consists of a pressure regulator, lubricator, and air supply mainfold.

Following is the list of topics that are covered:
-- Principles of Pneumatics
-- Flow Control Valves
-- The Pneumatic Cylinder
-- The Quick Exhaust Valve
-- The Pneumatic Motor
-- Sequencing Circuits
-- Characteristics and Behavior of Air
-- Directional Valves
-- The Pressure, Area and Force Relationship
-- The Pilot Operated Directional Valve
-- Time Delay Circuits
-- Sequencing Valve

Learning Materials:
1. Industrial Pneumatic Technology. Cleveland, Ohio: Parker Hannifin Corporation, 1980.
2. An Instructor's Guide for the text is available. It contains teaching aids, teaching procedures, answers to the end-of-chapter exercises, and test questions and answers. A transparency set is also available.

Audio-Visual Material:
1. The videotapes "Force Transmission Through a Fluid," "Energy Transmission Using a Pneumatic System," and "Control of Pneumatic Energy" are part of the Industrial Pneumatic Technology Series from Parker Hannifin. The series consists of twelve videotapes and an instructor's guide. Their address is: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland, OH 44112, (216)531-3000.

Resources:

1. Books
    - A. Wilson, F. Pneumatic Controls for Industrial Application. Dearborn, Michigan: American Society of Tool and Manufacturing Engineers, 1965.
    - B. Stewart, H. Pneumatics and Hydraulics. New York: Macmillan Publishing Company, 1987.
    - C. FESTO Corporation has numerous texts and manuals available including the following: Introduction to Pneumatics, Maintenance of Pneumatic Equipment and Systems, Single Memory and Logic Circuits, Pneumatic Applications, Pneumatic Controls, Pneumatics in Woodworking, Pneumatics in Packing, Cutting Costs with Pneumatics, Fundamentals of Control Technology, Programmable Logic Controllers, Pneumatics Workbook, Electro-Pneumatics Workbook, Programmable Logic Controllers Workbook, and Control Technology Dictionary. Their address is: FESTO Corporation, 395 Moreland Road, Hauppauge, NY 11788.
    - D. AMATROL has several manuals available that deal with pneumatics. Their address is: AMATROL, P.O. Box 2697, Jeffersonville, IN 47131, (812)288-8285.

2. Pamphlets:
    - A. "Armstrong Float Type Liquid Drainers" (Bulletin No. 401-G) is available from Armstrong Machine Works, Marketing Service Dept., 816 Maple Street, Three Rivers, MI 49093.
    - B. "Pneumatic Actuators and Components" (F-PA/PAS), "Pneumatic Actuators" (F-DA/SR), and "Pneumatic Actuator Accessories Handbook" (F-PA/AH) are available from Rick Davison, Jr., Watts Regulator Company, c/o Advance Industrial Marketing, Ltd., P.O. Box 87, 923 S. Bird Street, Sun Prairie, WI 53590, (608) 837-5005.

3. Audio-Visual Material:
    - A. "Pneumatics Explained" is a filmstrip/tape presentation available from Bergwall Productions, New York.
    - B. FESTO Corporation has the following videotapes available: "Pneumatic Principles and Working Elements," "Pneumatic Switching Logic and Operational Principles," "Pneumatic Motion, Timing and Control," and "Pneumatic/Electric and Electric/Pneumatic Converters." Also available are the following transparency sets: Compressed Air Production, Pneumatic Working Elements, Pneumatic Valves 1 and 2, and Electro-pneumatics 1 and 2. Cut-away models and posters are also available. Their address is given above.

C. "Basic Pneumatic Systems and Diagrams," "Pneumatic Instrument Tubing," "Pneumatic Control Equipment 1,2,and 3," "Pneumatic Actuators and Positioners," "Basic Pneumatic Control Systems," "Multi-Element Pneumatic Control Systems," "Troubleshooting Pneumatic Instrument Systems," "Tuning Pneumatic Control Systems," "Pneumatic Controllers," and "Fluid Power Systems-2: Pneumatics" are videotapes available from NUS Training Corporation.

D. "Air Distribution Systems," "Air Preparation - The Key to System Maintainability," "Pneumatic Components - Their Construction and Function," "Pneumatic Directional Control Valves," and "Sizing Pneumatic Components" are slide/tape programs available from Parker Hannifin. Also available are the following videotapes "Elements of Compressed Air," "Pneumatic Cylinders," and "Pneumatic Circuitry - Part 1 and 2." In addition, a pneumatics template is available. Their address is: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland OH 44112, (216)531-3000.

E. "Pneumatics Series" is a set of eight videotapes available from Video Training Resource, Inc.

Competency:

1. Describe the operation of and be able to identify the compressors of typical pneumatic systems.
2. Explain the purpose of aftercoolers, driers, and receivers in a pneumatic system.
3. Describe typical piping systems for a pneumatic system.
4. Demonstrate the ability to inspect a pneumatic system for leaks.
5. Demonstrate the ability to install a drain trap in a pneumatic system.

Instructional Objectives:

1. List two basic groups of air compressors and explain their operation.
2. Identify types of positive displacement compressors.
3. Explain the operation of positive displacement compressors.
4. Identify types of centrifugal compressors.
5. Explain the operation of centrifugal compressors.
6. State the purpose of a multi-stage compressor.
7. Describe ways of unloading or controlling the output of a compressor.
8. Explain why ventilation is important for an air-cooled compressor.
9. List three factors to consider when installing a compressor.
10. State the purpose of an aftercooler.
11. Identify four methods that provide drier air to a pneumatic system.
12. Explain the purpose of a receiver tank.
13. Describe three types of piping systems used in pneumatic systems.
14. List six factors that should be considered when laying out a pneumatic circuit.
15. List methods of leak detection in a pneumatic system.
16. Check a pneumatic system for leaks.
17. Install a drain trap in a pneumatic system.

Learning Activities:

1. Read Chapters 5 and 6 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 5 and 6.
3. Read "Drainage of Water and Oil from Compressed Air" (Bulletin 251-B) from Armstrong Machine Works.
4. View the videotapes "Compressors" and "Aftercoolers, Driers, Receivers - Air Distribution System" (Parker Hannifin).
5. Participate in sessions on a pneumatics trainer as provided by your instructor.

Application Exercises:

1. Check a pneumatic system for leaks.
2. Install a drain trap in a pneumatic system.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture pneumatics trainers are listed in Pneumatics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Industrial Pneumatic Technology. Cleveland, Ohio: Parker Hannifin Corporation, 1980.
2. An Instructor's Guide for the text is available. It contains teaching aids, teaching procedures, answers to the end-of-chapter exercises, and test questions and answers. A transparency set is also available.
3. "Drainage of Water and Oil from Compressed Air" (Bulletin 251-B) is available from Pamela G. Blasius, Marketing Services Department, Armstrong Machine Works, 816 Maple Street, Three Rivers, MI 49093, (616)273-1415.

Audio-Visual Material:

1. The videotapes "Compressors" and "Aftercoolers, Driers, Receivers - Air Distribution System" are part of the Industrial Pneumatic Technology Series from Parker Hannifin. The series consists of twelve videotapes and an instructor's guide. Their address is Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland, OH 44112, (216)531-3000.

Resources:

1. A listing of books and audiovisual materials is detailed in Pneumatics I.

Competency:

1. Identify check valves, cylinders, and motors and describe their basic operation and typical application.
2. Demonstrate the ability to repair/install a pneumatic cylinder.

Instructional Objectives:

1. Describe how a check valve works.
2. List the components of a pneumatic cylinder.
3. List types of seals used on a pneumatic cylinder.
4. Identify where seals are located on a pneumatic cylinder.
5. State the purpose of a stroke adjuster.
6. List six cylinder mounting styles.
7. List six types of pneumatic cylinders.
8. Explain how to size a cylinder.
9. Solve cylinder sizing problems.
10. Repair/install a pneumatic cylinder.
11. Explain the purpose of a stop tube.
12. Explain how a stop tube is selected.
13. Calculate stop tube length.
14. List three reasons why a cylinder may buckle.
15. Explain the purpose of cushions for a pneumatic cylinder.
16. Determine if a cylinder will be able to cushion a particular load.
17. Explain what determines the flow rate into a cylinder.
18. Calculate the flow rate for a pneumatic cylinder.
19. List four types of pneumatic motors.
20. Identify applications for various types of pneumatic motors.

Learning Activities:

1. Read Chapter 7 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapter 7.
3. View the videotape "Check Valve, Cylinders and Motors" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as provided by your instructor.

Application Exercises:

1. Repair/install a pneumatic cylinder.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture pneumatics trainers are listed in Pneumatics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Industrial Pneumatic Technology. Cleveland, Ohio: Parker Hannifin Corporation, 1980.
2. An Instructor's Guide for the text is available. It contains teaching aids, teaching procedures, answers to the end-of-chapter exercises, and test questions and answers. A transparency set is also available.

Audio-Visual Material:

1. The videotape "Check Valve, Cylinders and Motors" is part of the Industrial Pneumatic Technology Series from Parker Hannifin. The series consists of twelve videotapes and an instructor's guide. Their address is: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland OH 44112, (216)531-3000.

Resources:

1. A listing of books and audio-visual materials is detailed in Pneumatics I.

Competency:

1. Identify pneumatic directional control valves.
2. Describe the operation of pneumatic directional control valves.
3. Explain the basic function, operation, and placement of flow control valves, silencers, and quick exhaust valves.
4. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve in a pneumatic system.

Instructional Objectives:

1. Identify three ways directional valves can function.
2. Explain the function of a two-way directional valve.
3. Explain the function of a three-way directional valve.
4. Explain the function of a four-way directional valve.
5. Describe how and why a three-way directional valve can replace a four-way directional valve.
6. List four ways directional valves can be operated.
7. Explain what a spring offset valve is.
8. Explain what normally opened and normally closed valves are.
9. Describe the purpose of detents for directional valves.
10. List three center conditions of pneumatic directional valves.
11. Name two ways directional control valves are sealed.
12. Identify four basic types of shear action valves.
13. Describe how the four basic types of shear action valves seal.
14. Distinguish between a poppet valve and a shear action valve.
15. Size pneumatic directional controls by using the CV formula.
16. Disassemble, inspect, and reassemble a directional control valve.
17. List four factors that affect flow through an orifice.
18. List three types of variable orifices.
19. Explain the term "meter out" control.
20. Name the most common type of flow control valve found in a pneumatic system.
21. Explain what the term "jump" means for pneumatic controls.
22. Explain the purpose of a quick exhaust valve.
23. Explain the purpose of a silencer in a pneumatic system.

Learning Activities:

1. Read Chapters 8 and 9 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 8 and 9.
3. View the videotapes "Directional Control Valves" and "Flow Control Valves, Silencers, and Quick Exhausts" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as supplied by your instructor.

Application Exercises:

1. Disassemble, inspect and reassemble a directional control valve in a pneumatic system.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture pneumatics trainers are listed in Pneumatics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Industrial Pneumatic Technology. Cleveland Ohio: Parker Hannifin Corporation, 1980.
2. An Instructor's Guide for the text is available. It contains teaching aids, teaching procedures, answers to the end-of-chapter exercises, and test questions and answers. A transparency set is also available.

Audio-Visual Material:

1. The videotapes "Directional Control Valves" and "Flow Control Valves, Silencers, and Quick Exhausts" are part of the Industrial Pneumatic Technology Series from Parker Hannifin. The series consists of twelve videotapes and an instructor's guide. Their address is: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland, OH 44112, (216)531-3000.

Resources:

1. A listing of books and audiovisual materials is detailed in Pneumatics I.

Competency:

1. Explain the function of regulators, excess flow valves, boosters, and sequence valves that are found in a typical pneumatic system.
2. Describe the components of air preparation, their operation, and the sources of contamination for a pneumatic system.
3. Demonstrate the ability to repair/install a pressure regulator in a pneumatic system.
4. Demonstrate the ability to repair/install an air line filter in a pneumatic system.
5. Demonstrate the ability to repair/install a lubricator in a pneumatic system.
6. Demonstrate the ability to repair/install a FRL unit in a pneumatic system.

Instructional Objectives:

1. Describe the function of a sequence valve.
2. Describe the function of a pressure regulator.
3. List two applications of a pressure regulator in a pneumatic system.
4. Distinguish between a venting and non-venting type pressure regulator.
5. Distinguish between a piston type and diaphragm type regulator.
6. List two advantages of a pilot controlled regulator over a standard regulator.
7. Calculate the correct size regulator for a particular pneumatic circuit.
8. Repair/install a pressure regulator in a pneumatic system.
9. Describe when dual regulation is used in a pneumatic system.
10. Explain the purpose of a booster in a pneumatic system.
11. Name two types of boosters.
12. Explain the purpose of an excess flow valve in a pneumatic system.
13. Calculate yearly cost savings by comparing pneumatic circuits.
14. Describe three sources of contaminants in a pneumatic system.
15. List three contaminant types found in a pneumatic system.
16. Explain how a micrometer seal is used to measure contaminants.
17. Describe the function of an air line filter.
18. Identify the parts of an air line filter.
19. Distinguish between depth type and edge type filter elements.
20. Explain what a nominal rating is for a filter.
21. Repair/install an air line filter in a pneumatic system.
22. Explain the purpose of an oil removal filter.
23. Describe how a filter is drained.
24. List three steps in selecting a filter.
25. Explain the purpose of air line lubrication in a pneumatic system.
26. List three types of air line lubricators.
27. Identify three reasons for having a lubricator in a pneumatic system.
28. Repair/install a lubricator in a pneumatic system.
29. Explain what a FRL unit is.
30. Repair/install a FRL unit in a pneumatic system.

Learning Activities:

1. Read Chapters 10 and 11 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 10 and 11.
3. View the videotapes "Regulators, Excess Flow Valves, Boosters and Sequence Valves" and "Air Preparation" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as supplied by your instructor.

Application Exercises:

1. Repair/install a pressure regulator in a pneumatic system.
2. Repair/install an air line filter in a pneumatic system.
3. Repair/install a lubricator in a pneumatic system.
4. Repair/install a FRL unit in a pneumatic system.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Several of the companies that manufacture pneumatics trainers are listed in Pneumatics I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Industrial Pneumatic Technology. Cleveland, Ohio: Parker Hannifin Corporation, 1980.
2. A Instructor's Guide for the text is available. It contains teaching aids, teaching procedures, answers to the end-of-chapter exercises, and test questions and answers. A transparency set is also available.

Audio-Visual Material:

1. The videotapes "Regulators, Excess Flow Valves, Boosters, and Sequence Valves" and "Air Preparation" are part of the Industrial Pneumatic Technology Series from Parker Hannifin. The series consists of twelve videotapes and an instructor's guide. Their address is: Parker Hannifin Corporation, Fluidpower Training, 17325 Euclid Avenue, Cleveland, OH 44112, (216)531-3000.

Resources:

1. A listing of books and audiovisual materials is detailed in Pneumatics I.

Competency:

1. Identify and use basic drafting tools.
2. Draw freehand sketches.
3. Demonstrate basic drafting techniques.
4. Create multi-view drawings.

Instructional Objectives:

1. Choose and effectively use the correct drawing instruments.
2. Scale prints accurately with the architect's scale.
3. Identify the types of freehand drawings.
4. Draw freehand sketches of horizontal, vertical, and angular lines.
5. Draw freehand sketches of angles, arcs, and circles.
6. Draw multi-view (top, front, right side) sketches of objects.
7. Draw isometric circles and arcs.
8. Describe the different types of drawings in a pipe drafting project.
9. Identify the types of lines used in pipe drafting.
10. Trace runs of pipe on drawings.

Learning Activities:

1. Participate in class lectures and discussions on drafting instruments and freehand sketching.
2. Read pp. 8-29 in Orthographic Projection Simplified.
3. Complete the Problems on pp. 30-65 in Orthographic Projection Simplified as assigned by your instructor.
4. Read pp. 66-67 in Orthographic Projection Simplified.
5. Complete the Problems on pp. 68-81 in Orthographic Projection Simplified as assigned by your instructor.
6. Read p. 82 and complete the Problems on pp. 83-93 in Orthographic Projection Simplified.
7. Read Chapter 1 in Process Pipe Drafting.
8. Complete the Review Questions (1-20) at the end of Chapter 1 in Process Pipe Drafting.
9. Complete Assignment Sheet 1, "Basic Drafting Techniques."
10. Complete Assignment Sheet 2, "Basic Freehand Sketching."
11. View the videotape "Reading Diagrams" (NUS Training Corporation).

Application Exercises:

1. Trace runs of pipe on drawings.
2. Sketch simple orthographic drawings.
3. Measure dimensions from blueprints using an architect's scale.

Evaluation/Checkout:

1. Submit the assigned Problems from Orthographic Projection Simplified.
2. Submit the Review Questions from Process Pipe Drafting.
3. Submit Assignment Sheets 1 and 2.
4. Submit your checklist of application exercises.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Basic drafting tools and architect's scale will be needed to explain and demonstrate basic drafting techniques and freehand sketching. See Instructional Objectives 1-5 for the material to be covered. The depth of the presentation will depend upon the apprentices' backgrounds.
2. Quinlan, C. Orthographic Projection Simplified. Mission Hills, California: Glencoe Publishing Company, 1987. The readings and problems that should be covered in the book on multi-view drawings should be determined by the needs and backgrounds of the apprentices. An apprentice with a basic drafting background should not need to do this section. One of the tests in the back of the book can be used to evaluate background. The answers for these tests are included with this unit.
3. Shumaker, T. Process Pipe Drafting. South Holland, Illinois: Goodheart-Willcox Company, Inc., 1985. An instructor's guide is available and contains the answers to the review questions and problems at the end of the chapters.
4. A copy of the assignments sheets is included with this unit.

Audio-Visual Material:

1. The videotape "Reading Diagrams" is available from NUS Training Corporation and is part of the Refinery Operations series. It explains the types of diagrams associated with process system operations and the types of information they contain, including commonly used symbols, abbreviations, and other information found in a diagram legend. It also shows how various kinds of diagrams-such as flow diagrams and piping and instrumentation diagrams-can be used to understand process system interrelationships. A workbook is supplied with the unit.

Resources:

1. Books:
   - A. Shumaker, T. Process Piping Blueprint Reading. Englewood Cliffs, New Jersey: Prentice-Hall, 1982.
   - B. Weaver, R. Modern Basic Drafting. Houston, Texas: Gulf Publishing Company, 1979.
   - C. Weaver, R. Process Pipe Drafting, 3rd Ed. Houston, Texas: Gulf Publishing Company, 1986.
   - D. Weaver, R. Process Piping Design. Houston, Texas: Gulf Publishing Company, 1973.
   - E. Weaver, R. Blueprint Reading Basics. Houston, Texas: Gulf Publishing Company, 1982.
   - F. Lamit, G. Piping Systems: Drafting and Design. Englewood Cliffs, New Jersey: Prentice-Hall, 1981.

G. Hartman, W. and Williams, F. Pipe Drafting. New York: McGraw-Hill, 1981.

H. Sherwood, D. Piping Guide, 2nd Ed. San Francisco, California: Syentek Books Company, 1989. An excellent reference guide for the design and drafting of industrial piping systems.

I. Davis, R. and White, D. Pipe Drafting. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1983. This presents a comprehensive, competency based approach to pipe drafting.

J. Giachino, J. and Beukema, H. Freehand Sketching. Homewood, Illinois: American Technical Publishers, 1983.

K. Giachino, J. and Beukema, H. Everyday Sketching and Drafting. Homewood, Illinois: American Technical Publishers, 1984.

L. Orthographic Projection. Athens, Georgia: American Association for Vocational Instructional Materials, 1986. This is a computer software program that illustrates visually the concepts of orthographic projection theory. There are twenty three assignments. A student manual and teacher's manual is available.

M. Blueprint Reading and Sketching. (Naval Education and Training Command Rate Training Manual - NAVEDTRA 10077-F). Washington, D.C.: United States Government Printing Office, 1977. Stock Ordering No. 0502-LP-3875.

2. Audio-Visual Material:

A. Gulf Publishing Company - Video Publishing has videotapes which corresponds to Rip Weaver's texts. The series corresponding to Process Pipe Drafting covers the following topics:

1. Equipment and terms.
2. Basic piping data.
3. Orthographic projections.
4. Flow diagrams.
5. Instrumentation.
6. Specifications and equipment details.
7. Equipment and coordinate systems.
8. Isometric configurations.
9. Detail dimensioning.
10. Dimensioned isometrics.

The Piping Familiarization Series covers the following topics:

1. Flanges, fittings and pipe.
2. Valves.
3. Orthographic projections.
4. Utility system.
5. Flow diagrams.
6. Fractionating towers.
7. Pressure Vessels.
8. Pumps and compressors.
9. Exchangers.
10. Fired heaters.
11. Instrumentation.
12. Pipe fabrication.
13. Piping isometrics.

The series corresponding to Blueprint Reading Basics covers the following topics:

1. Dimensioning.
2. Math Review and Math Shortcuts.
3. Plant Coordinate Systems.
4. Reading Drawings.
5. Pipe Drawings - Terms and Equipment.
6. Pipe Drawings - Valves, Flanges and Pipe.
7. Pipe Drawings - Fittings and Orthographic Projections.
8. Pipe Drawings - Detail Dimensioning and Symbology.
9. Pipe Fabrication Drawings.

They are available from Gulf Publishing Company Video, P.O. Box 2608, Houston, TX 77252-2608, (713) 529-4301.

B. "Shape Descriptions" and "Lettering" are videotapes from filmstrips available from AAVIM, 120 Driftmier Center, Athens, GA 30602, (404) 542-2586.

C. "Reading Blueprints - A Series" are videotapes available from TPC Training Systems, 1301 S. Grove Ave., P.O. Box 1030, Barrington, IL 60010, (312) 381-1840.

Assignment Sheet 1
Basic Drafting Techniques

1. Use an architect's scale to draw lines using the scale indicated to the length given. Begin at the dot.

	Scale	Length
a. .	1/2" = 1'0"	9' 5 1/2"
b. .	1/8" = 1'0"	40' 4"
c. .	3/8" = 1'0"	8' 3"
d. .	3/4" = 1'0"	9' 10 1/2"
e. .	1/4" = 1'0"	22' 7"
f. .	1/8' = 1'0"	4' 0"

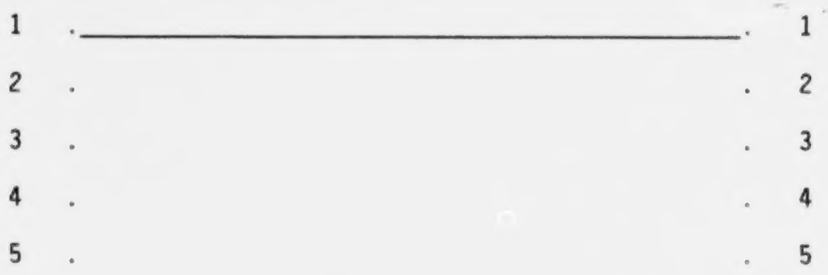
2. Using the scale 1/8" = 1'0", make a circle 4 feet in diameter.

3. Using the same scale as in Problem 2, make a circle 10 feet in diameter with a circle 5 feet in diameter inside of it on the same center.

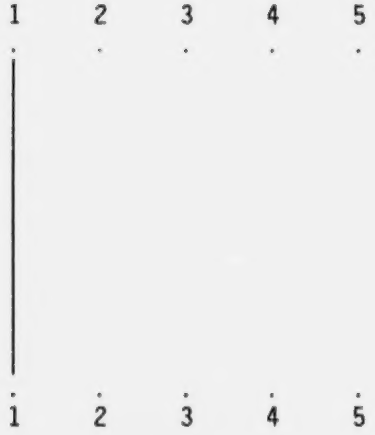
4. Using the architect's scale, measure the distance between the outside of the smaller circle to the inside of the larger circle (in Problem 3). How many feet is it?

Assignment Sheet 2
Basic Freehand Sketching

1. Sketch the lines as indicated.


1
2
3
4
5
1
2
3
4
5

HORIZONTAL


1
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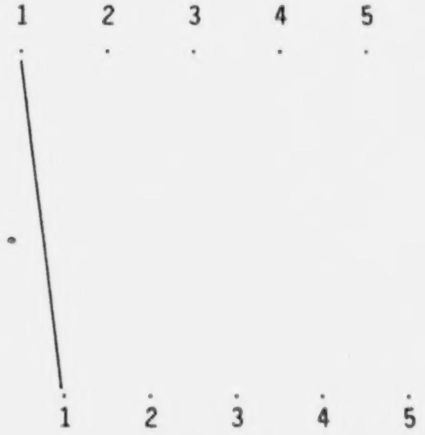
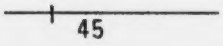
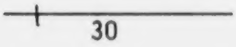

1
2
3
4
5
1
2
3
4
5

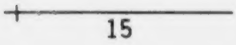
VERTICAL

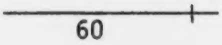
ANGULAR

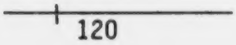
2. Sketch the required angles from the horizontal. Short vertical mark should be vertex of angle.

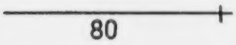












3. Sketch the circles as indicated.

1 1/2" Diameter +

2" Diameter +

3 1/2" Diameter +

Answers to Tests in Orthographic Projection Simplified

Top View Test (P. 124)

4, 22, 4, 9
20, 22, 16, 2
14, 18, 6, 7
11, 24, 13, 23
7, 8, 19, 12

Front View Test (P. 125)

12, 24, 2, 22
2, 7, 2, 9
12, 22, 19, 15
15, 5, 5, 1
18, 19, 9, 11

Right Side View Test (P. 126)

3, 13, 23, 1
10, 23, 22, 20
1, 15, 5, 18
9, 11, 12, 16
7, 6, 19, 21

Hidden Line Test (P. 127)

4, 13, 19, 2
21, 15, 24, 9
6, 24, 19, 11
8, 17, 23, 7
10, 20, 3, 12

Three View Test (P.128)

5, 10, 22, 3
12, 24, 19, 15
4, 20, 13, 1
17, 6, 11, 14
23, 2, 16, 12

Competency:
1. Describe pipe and pipe fittings in terms of pipe drafting.
2. Explain how valves and measurement instruments are shown in pipe drafting.
3. Explain how pumps, tanks and piping equipment are shown in pipe drafting.
4. Create multi-view drawings of pipe and fitting assemblies.
5. Interpret drawings of pipe and fitting assemblies.

Instructional Objectives:
1. Describe two methods of classifying pipe thickness.
2. Identify various types of pipe fittings.
3. Sketch the symbols that are used to stand for pipe fittings.
4. Sketch multi-views of double line and single line pipe fittings.
5. Use fitting charts to obtain welding fittings' and welding flanges' dimensions.
6. Sketch multi-views of simple piping assemblies.
7. Name three functions of valves.
8. Sketch the symbols that are used to stand for valves and measurement instruments.
9. Sketch in missing valves and instruments in flow diagrams.
10. Use manufacturer's valve specifications to find dimensions.
11. Convert an isometric pipe assembly to a single line and double line sketch.
12. Trace runs of pipe and identify valves, fittings, pumps, and tanks on simple piping drawings.
13. Use specifications to obtain information from drawings.
14. Sketch the symbols that are used to stand for pumps, tanks, and piping equipment.
15. Describe the information that is found on the bill of material.
16. Calculate the needed dimensions and elevations in drawings.

Learning Activities:
1. Read Chapters 2, 3, and 4 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 2: 1-19, Problems 2-1, 2-2, 2-5, and 2-6; Chapter 3: 1-14, Problems 3-1, 3-2, 3-3, 3-4, and 3-7; and Chapter 4: 1-11, Problems 4-1, 4-4, and 4-5.
3. View the videotape "Reading Piping Drawings" (Marshall Maintenance Productions).

Application Exercises:
1. Trace runs of pipe and identify valves, fittings, pumps, and tanks.
2. Use specifications to obtain information from drawings.
3. Calculate the needed dimensions and elevations in drawings.

Evaluation/Checkout:

1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the tasks.

Learning Materials:

1. Shumaker, T. Process Pipe Drafting. South Holland, Illinois: Goodheart-Wilcox Company, Inc., 1985. An instructor's guide is available and contains the answers to the review questions and problems at the end of the chapters.

Audio-Visual Material:

1. The videotape "Reading Piping Drawings" is available from Marshall Maintenance Productions. The tape is designed for the pipefitter or millwright. This program reduces complicated piping drawings to simple terms. Starting with the title block, the program covers symbols and notations; dimensional, elevation & plan drawings; spool drawings; and more.

Resources:

1. Books
   A. A listing of books is detailed in Process Pipe Drafting I.

2. Audio-Visual Materials:
   A. "Reading Schematics and Symbols - A Series" is available from TPC Training Systems. Two of the tapes cover Piping Diagrams and Piping Symbols. Contact TPC Training Systems, 1301 South Grove Ave., P.O. Box 1030, Barrington, IL 60010, (312)381-1840.

Competency:
1. Describe the purpose of a flow diagram.
2. Explain the parts of a flow diagram.
3. Describe the purpose of elevation drawings and section drawings.
4. Describe the components of a piping plan.
5. Interpret the information on flow diagrams, elevation drawings, section drawings, and piping plans.

Instructional Objectives:
1. Identify the function of a flow diagram.
2. List the components of a flow diagram.
3. Identify the symbols that are used in drawing a flow diagram.
4. Sketch the symbols that are used in drawing a flow diagram.
5. Explain what a pipe specification symbol is.
6. Sketch the equipment, valves, and instruments on a flow diagram.
7. List the components of a piping plan.
8. Explain how dimensioning is done on a piping plan.
9. Describe how project specifications are used on a piping plan.
10. Identify the purposes of elevation and section drawing.
11. Explain how dimensioning is done on elevation and section drawings.
12. Calculate elevations of items found on piping drawings.
13. Sketch elevation views of pipe and fitting assemblies.
14. Describe how notes, abbreviations, and revisions are used on pipe drawings.
15. Identify abbreviations used on piping drawings.
16. Interpret notes on piping drawings.
17. Use flow diagrams, elevations drawings, and section cuts to trace given runs of pipe.
18. Use flow diagrams, elevation drawings, and sections cuts to interpret information about given runs of pipe.

Learning Activities:
1. Read Chapters 5, 6, and 7 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 5: 1-11, Problem 5-2; Chapter 4: Problem 4-3; Chapter 6: 1-12, Problems 6-2 and 6-4; and Chapter 7: 1-18, Problems 7-1 and 7-2.

Application Exercises:
1. Use flow diagrams, elevation drawings, and section cuts to trace given runs of pipe.
2. Use flow diagrams, elevation drawings, and section cuts to interpret information about given runs of pipe.

Evaluation/Checkout:
1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Shumaker, T. Process Pipe Drafting. South Holland, Illinois: Goodheart-Wilcox Company, Inc., 1985. An instructor's guide is available and contains the answers to the review questions and problems at the end of the chapters.

Resources:

1. Books
    A. A listing of books is detailed in Process Pipe Drafting I.

Competency:
1. Define what an isometric drawing is.
2. Describe the layout of an isometric drawing.
3. Sketch isometric piping and fittings.
4. Explain the purpose and layout of a spool drawing.
5. Read a specifications book and develop a material list for a specific job.

Instructional Objectives:
1. Identify the function of an isometric drawing.
2. Explain why it is always important to orient yourself with the north arrow in an isometric drawing.
3. Identify how symbols are oriented on isometric drawings.
4. Demonstrate the ability to do freehand isometric drawings.
5. Demonstrate the ability to dimension and letter freehand isometric drawings.
6. Interpret information found on isometric drawings.
7. Sketch an isometric drawing from an orthographic drawing.
8. Differentiate between isometric drawings and spool drawings.
9. Interpret information found on spool drawings.
10. Sketch a spool drawing from an isometric drawing.
11. Construct a bill of material for a spool drawing.
12. Use a specifications book and an isometric drawing and construct a material list for a specific job.

Learning Activities:
1. Read Chapter 8 and 9 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 8: 1-11, Problems 8-2, 8-4, and 8-5; and Chapter 9: 1-7, Problems 9-2, 9-3, 9-4, and 9-5.

Application Exercises:
1. Interpret information found on isometric drawings.
2. Interpret information found on spool drawings.
3. Use a specifications book and an isometric drawing and construct a material list for a specific job.

Evaluation/Checkout:
1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Equipment:
1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Material:

1. Shumaker, T. Process Pipe Drafting. South Holland, Illinois: Goodheart-Wilcox Company, Inc., 1985. An instructor's guide is available and contains the answers to the review questions and problems at the end of the chapters.

Resources:

1. Books:
    - A. A listing of books is detailed in Process Pipe Drafting I.

Competency:

1. Explain stress in relation to piping material.
2. Evaluate strength of piping material.
3. Interpret expansion/contraction effects.

Instructional Objectives:

1. Define tension stress, compression stress, and shearing stress.
2. Identify the properties of metals.
3. Define elasticity, strength, hardness, toughness, plasticity, ductility, malleability, brittleness, weldability, machinability, thermal conductivity, and corrosion resistance.
4. Define expansion and contraction.
5. Explain the coefficient of linear expansion.
6. Describe the function of expansion joints.
7. List types of expansion joints.

Learning Activities:

1. Read the Properties of Metals Information Sheet.
2. Read the Expansion/Contraction Information Sheet.
3. Complete the Properties of Metals Worksheet.

Evaluation/Checkout:

1. Submit the Properties of Metals Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:

1. A copy of the information sheets, worksheet and answers, and the test and answers is included with this unit.

Properties of Metals Information Sheet

Can you define a metal? Chemical elements are considered to be metals if they are lustrous, hard, good conductors of heat and electricity, malleable, ductile, and heavy. Some metals are heavier than others; some are more malleable than others; and some are better conductors of heat and electricity. These properties are known as "metallic properties," and chemical elements that possess these properties to some degree are called metals. Chemical elements that do not possess these properties are called nonmetals. Oxygen, hydrogen, chlorine, and iodine are examples of nonmetallic chemical elements.

Chemical elements that behave sometimes like metals and sometimes like nonmetals are often called metalloids. Carbon, silicon, and boron are examples of metalloids.

An alloy may be defined as a substance that has metallic properties and is composed of two or more elements. The elements that are used as alloying substances are usually metals or metalloids. By combining metals and metalloids, it is possible to develop alloys that have the particular properties required for a given use.

STRESS AND STRAIN

When external force is applied to any solid material, the material is subjected to stress. Many of the properties of metals can best be understood in terms of the manner in which they react to stress. Therefore, before considering the properties of metals and alloys, let us examine the concepts of stress and strain.

Load, which is usually measured in pounds, is the external force applied to a material. When the load is applied, reaction forces to the load occur throughout the material. The reaction forces are stresses. Why do these forces occur when a load is applied to a material? Newton's third law of motion states that "to every force or action, there is an equal and opposite reaction." Stress, therefore, is the "equal and opposite" reaction to the externally applied load. It is defined as the force per unit area resisting the load. Unit area is important. The unit area may be stated as a square inch, a square foot, or any other predetermined amount of stress that the material will be subjected to. When the load is applied, it is distributed equally throughout the cross section of the material. For example, suppose two round metal rods with cross-sectional areas of 1 square inch and 2 square inches are each supporting a 2000-pound weight. The load or external force is the same on both, but since the cross-sectional areas are different and the load is distributed equally over the cross-sectional areas, the stresses in the two rods are also different.

You can see from the example that the stress is equal to the load divided by the cross-sectional area. That is, equal portions of the load are distributed equally over the cross-sectional area. Stress is usually measured in pounds (for load) per square inch (for area). Conversely, the load can be determined by multiplying the stress by the cross-sectional area.

Strain is the deformation or change in shape caused by the load. Some strain always occurs as a reaction to a load. The amount of strain depends on the magnitude and duration of the stress caused by the load. It also depends on the type and condition of the material. Strain is measured in inches per inch or in percentage. Thus, when a load is applied to a bar in tension, the bar will elongate (be strained) some fraction of an inch for each inch of bar (the strain will be the same in each inch of bar). If strain is being measured in percentage, the bar will be elongated a certain percentage; that is, the total length of the bar will be increased a certain amount which will be a percentage of the original length.

Stress occurs because molecular forces within the material resist the change of shape that an applied load tends to produce. In other words, stress results from the resistance of the molecules to being shifted around, pulled apart, or squeezed together. Because stress involves molecular forces, a piece of metal that is subjected to a load develops an enormous number of stresses, rather than just one stress. If you had more than a very few molecules, you would have to draw thousands or perhaps millions of arrows to indicate all the molecular forces involved. We often speak of stress as though it were one internal force, acting in one direction--that is, the direction opposite to the direction of the applied load. In other words, we consider the TOTAL EFFECT of all the molecular stresses, rather than trying to consider each set of molecular stresses separately.

The manner in which the load is applied determines the type of stress that will develop. Applied forces are usually considered as being of three basic kinds: tension (or tensile) forces, compression forces, and shearing forces. The basic stresses, therefore, are tension (or tensile) stresses, compression stresses, and shearing stresses. Complex stresses such as bending stresses and torsional stresses are combinations of two or more of the basic stresses.

TENSION STRESS

Tension stresses develop when a material is subjected to a pulling action. If, for example, a cable is fastened to an overhead clamp and a weight is attached to the free end, tension stresses develop within the cable. The tension stresses resist the tension forces that tend to pull the cable apart.

COMPRESSION STRESS
Compression stresses develop within a material to oppose the forces that tend to compress or crush the material. A column that supports an overhead weight is said to be in compression, and the internal stresses that develop within the column are compression stresses.

SHEARING STRESS
Shearing stresses develop within a material when opposite external forces are applied along parallel lines in such a way as to tend to cut the material. Shearing forces tend to separate material by sliding part of the material in the opposite direction. The action of a pair of scissors is an example of shear forces and shear stresses. The scissors apply shear forces, and the material being cut resists the shear forces by its internal shear stresses. Forces also tend to produce shear in a rivet.

BENDING STRESS
Bending stresses develop when a material is subjected to external forces that tend to bend it. When a load is applied to a beam, the upper surface is in compression and the lower surface is in tension.

TORSIONAL STRESS
Torsional stresses develop in a material when external forces are applied in such a way that they tend to produce rotation. A ship's shaft, for example, rotates when the external applied forces are greater than the internal torsional stresses developed in the shaft. Torsional stress is primarily a special form of shear stress, although it may also involve some compression stress and some tension stress.

PROPERTIES OF METALS
The particular properties that we require of any metal or alloy depend upon the use we will make of the material. For example, a boiler tube must have high tensile strength, the ability to conduct heat, and the ability to resist deformation or creep at high temperatures; an electric wire must be able to conduct electricity; a knife blade must have the property of hardness; a spring must be elastic; a saltwater piping system must resist corrosion; and a piece of metal that is to be drawn out into a wire must possess the property known as ductility. The following sections deal with some important properties of metals and alloys.

ELASTICITY
As previously noted, a deformation or change of shape (strain) occurs when a material is subjected to external forces that cause stresses in the material. The ability of a material to return to its original size and shape after strain is the property known as elasticity.

All materials are elastic to some extent. It may surprise you to learn that a piece of steel is more elastic than a rubber band. The rubber band stretches more than the steel since it is more easily strained, but the steel returns more nearly to its original shape and size and is, therefore, more truly elastic. Glass is also more elastic than rubber.

The greatest stress that a material is capable of withstanding without taking a permanent set (that is without becoming permanently deformed) is known as the ELASTIC LIMIT. Below the elastic limit, the amount of strain is directly proportional to the amount of stress and, therefore, to the amount of externally applied force. Above the elastic limit, however, the amount of deformation that results from an increase in load is way out of proportion to the increase in load.

Strain may be axial, angular, or both, depending upon the nature of the applied load and the stresses that are developed within the material to withstand the applied load. When the elastic limit is exceeded through the application of an axial load, the material will be permanently deformed either by ELONGATION or by COMPRESSION. When the applied load is not axial (as in shear and torsion), the resulting strain is angular and, if permanent deformation results, the deformation is also angular.

As noted before, the amount of strain is proportional to the amount of stress up to (or almost up to) the elastic limit. The ratio of stress to strain is, therefore, a constant for each material. This constant, which is called the MODULUS OF ELASTICITY, is obtained by dividing the stress by the strain which is the elongation caused by that stress. For example, suppose that a certain material is so loaded that the internal stress developed in tension is 30,000 psi and that with this stress the material elongates or is strained 0.0015 inch per inch. The modulus of elasticity (E) of this material is

$$E = \frac{\text{Stress (psi)}}{\text{Elongation (inch per inch)}}$$

$$= \frac{30{,}000 \text{ (psi)}}{0.0015 \text{ inch per inch}}$$

$$= 20{,}000{,}000 \text{ psi}$$

The modulus of elasticity is frequently used to determine the amount of elongation that will occur when a given stress is developed in the material. For this purpose, you divide the stress by the modulus of elasticity to obtain the elongation (inch per inch) that will occur.

Closely related to the elastic limit of a material is the YIELD POINT. The yield point is the stress at which deformation of the material first increases markedly without any increase in the applied load. The yield point is always somewhat above the elastic limit. When the stresses developed in a material are greater than the yield point (or, as it is sometimes called, the yield strength), the material is permanently deformed.

STRENGTH

Strength is the property that enables a material to resist deformation. ULTIMATE STRENGTH is the maximum stress which a material is capable of withstanding in tension, compression, or shear. TENSILE STRENGTH, or the ultimate strength of a material in tension, is the term most frequently used to describe the strength of a material.

Some materials are equally strong in compression, tension, and shear. However, many materials show marked differences. For example, cured portland cement has an ultimate strength of 2,000 psi in compression, but only 400 psi in tension. Carbon steel has an ultimate strength of 56,000 psi in tension and in compression, but an ultimate strength in shear of only 42,000 psi. In dealing with ultimate strength, therefore, the kind of loading (tension, compression, or shear) should always be stated.

If a material is stressed repeatedly, in a cyclical manner, it will probably fail at a loading that is considerably below its ultimate strength in tension, compression, or shear. For example, you can break a thin steel rod with your hands after it has been bent back and forth several times in the same place, although you could not possibly cause an identical rod to fail in tension, compression, or shear merely from force applied by hand. This tendency of a material to fail after repeated stressing at the same point is known as FATIGUE.

HARDNESS

The property of hardness has been defined as the ability of a material to resist penetration. Because there are several methods of measuring hardness, the hardness of a material is always specified in terms of the particular test that has been used to measure this property.

To get a simple idea of the property of hardness, consider lead and steel. You can scratch lead with a pointed wooden stick, but you can not scratch steel with such a stick. Steel is harder than lead.

TOUGHNESS

Toughness is the property that enables a material to withstand shock, to endure tensile stresses, and to be deformed without breaking. Another way of expressing this is to say that a tough material is one which can absorb a lot of energy before breaking. Toughness does not exist in metals that do not have high tensile strength; however, metals that are both strong and hard tend to have less toughness than metals that are softer and have less tensile strength.

Toughness is definitely related to the property of plasticity; materials must be plastic in order to be tough.

PLASTICITY

Materials that can withstand extensive permanent deformation without breaking or rupturing are said to be highly plastic. Note the use of the word "permanent" in this statement; the term PLASTIC DEFORMATION is used to indicate a PERMANENT change of shape. Modeling clay is an example of a highly plastic material since it can be deformed extensively and permanently without rupturing. Clay could scarcely be called tough, however, even though it is highly plastic.

Plasticity is in some ways the opposite of brittleness and in other ways the opposite of elasticity. A material that is brittle will break without showing deformation. Such a material is not very plastic. A material that is highly elastic will return to its original shape after strain; consequently, such a material does not show a high degree of plasticity (below the elastic limit for the substance). Most metals are elastic, rather than plastic, up to the elastic limit; above the elastic limit, they tend to have the property of plasticity.

Plasticity, like many other properties, is relative. To some degree, all substances are plastic. Even glass, which is usually considered to be a nonplastic material, is plastic if an external force is applied to it very slowly. If you want to demonstrate this to yourself, take a sheet of glass and lay it in a horizontal position in such a way that it is supported only at the ends. Then put a weight in the middle of the glass. After several days (or possibly weeks, depending upon the kind of glass you use), you will be able to observe a visible deformation of the glass.

The substance known as "Silly Putty" is an even better example of the relative nature of the property of plasticity. When you slowly press or mold "Silly Putty," it is more plastic than chewing gum; throw it against the floor and it may either bounce like a rubber ball or break into pieces; hit it sharply with a hammer, and it will shatter almost like glass.

DUCTILITY AND MALLEABILITY

The properties known as ductility and malleability are special cases of plasticity. Ductility is the property that makes it possible for a material to be drawn out into a thin wire or, in other words, it is the property that enables the materials to withstand extensive permanent deformation from TENSION. Malleability is the property that makes it possible for a material to be stamped, hammered, or rolled into thin sheets; a malleable material is one that can withstand extensive permanent deformation from COMPRESSION.

Most metals that exhibit one of these properties also exhibit the other. However, this is not always true. Lead, for example, is very malleable (it can be permanently deformed in compression without breaking), but it is not ductile (it cannot be permanently deformed in tension to any great extent).

CREEP RESISTANCE

The term "creep" describes a special kind of plastic deformation that occurs very slowly at high temperatures when the material is under a constant stress. It is interesting to note that this stress may be considerably less than the yield point of the material at room temperature. Because creep occurs very slowly at or below room temperature (so slowly, in fact, that years are required to complete a single creep test), the importance of this type of plastic deformation has not been recognized until fairly recently.

BRITTLENESS

We have already defined brittleness, indirectly, by saying that it is in some way the opposite of toughness. A brittle material is one that fractures before exhibiting any noticeable permanent deformation.

WELDABILITY AND MACHINABILITY

Although not strictly properties, in the sense of the other properties we have discussed, weldability and machinability are important practical considerations in the fabrication or repair of any metal part. Weldability refers to the relative ease with which a metal may be welded. Machinability describes the ease with which a metal may be turned, planed, milled, or otherwise shaped in the machine shop. Some metals are not easily machined because they are too hard. Some soft metals are not easily machined because they are too tough. Both weldability and machinability are really based upon the combination of other properties of the material, rather than being properties in themselves.

THERMAL CONDUCTIVITY

The thermal conductivity of a substance is the measure of the ability of the substance to conduct heat. Thermal conductivity is expressed numerically, but you have to be cautious about trying to interpret the number until you know what definition was followed in arriving at the number. Several definitions are commonly used, including:

1. Thermal conductivity is the quantity of heat, in British thermal units (Btu), that flows during 1 hour through a piece of material that is 1 square foot in area and 1 foot thick when there is a 1 degree F difference in temperature between the two faces.
2. Thermal conductivity is the quantity of heat (Btu) that flows during 1 hour through a piece of material that is 1 square foot in area and 1 inch thick when there is a 1 degree F temperature difference.
3. Thermal conductivity is the quantity of heat that flows during 1 hour through a 1-inch cube when there is a 1 degree F temperature difference.

As you can see, the number used to indicate the thermal conductivity of any substance cannot be the same in all of these definitions. Consequently, it is important to notice the way in which thermal conductivity is defined before accepting a numerical value for this property.

Thermal conductivities should also be specified in terms of the temperature at which the conductivity test is made since the temperature definitely affects this property. In general, the thermal conductivity of metals decreases as the temperature increases. For example, the thermal conductivity of pure iron is 39.0 at 64 degrees F, but is 36.6 at 212 degrees F (by the first definition of thermal conductivity). However, in some metals there is an increase in thermal conductivity with an increase in temperature. The thermal conductivity of aluminum is 117 at 64 degrees F, but it is 119 at 212 degrees F (again, by the first definition). Most metals have high thermal conductivity as compared with nonmetallic substances.

CORROSION RESISTANCE

Corrosion resistance is the property that enables a material to resist entering into chemical combination with other substances. Most metals are easily corroded, however, as shown by the fact that pure metals occur only rarely in nature.

The presence of impurities, or the presence of alloying elements, may greatly alter the corrosion resistance of a metal. For example, the zinc which is known as "commercially pure" contains a small amount of impurities; this grade of zinc corrodes about 10,000 times as fast as zinc that is chemically pure. On the other hand, many alloys have been developed for the particular purpose of increasing the corrosion resistance of the material. For example, pure iron would be entirely unsuitable for use in boilers because it has very poor resistance to corrosion, particularly at high temperatures; yet alloys composed primarily of iron are used successfully for this service.

Properties of Metals/Alloys

Toughness	Brittleness	Ductility	Malleability	Corrosion Resistance
Copper	White Cast Iron	Gold	Gold	Gold
Nickel	Gray Cast Iron	Silver	Silver	Platinum
Iron	Hardened Steels	Platinum	Aluminum	Silver
Magnesium	Bismuth	Iron	Copper	Mercury
Zinc	Manganese	Nickel	Tin	Copper
Aluminum	Bronzes	Copper	Lead	Lead
Lead	Aluminum	Aluminum	Zinc	Tin
Tin	Brass	Tungsten	Iron	Nickel
Cobalt	Structural Steels	Zinc		Iron
Bismuth	Zinc	Tin		Zinc
	Monel	Lead		Magnesium
	Tin			Aluminum
	Copper			
	Iron			

* Metals/alloys are ranked in descending order of having the property named in the column heading.

Reference:

Hull Maintenance Technician 3 & 2, Volume 1 (NAVETRA 10571).
Washington, D.C.: U.S. Government Printing Office, 1984.
(Stock Ordering No. 0502-LP-052-8630)

Expansion/Contraction Information Sheet

EXPANSION AND CONTRACTION

The dimensions of a pipe change in proportion to its original dimensions and to the amount of change in temperature. Piping expands both in length and in diameter. The change in diameter is usually slight, however, and for most purposes can be disregarded. The amount of LINEAR expansion or contraction (change in length) of piping is of great importance both in the design of piping systems and in the replacement of portions of systems. The linear change that is of most interest is the difference between the length of the pipe at room temperature and at the operating temperature of the system.

The amount of linear expansion or contraction per unit length of a material per degree change in temperature is called the COEFFICIENT OF LINEAR EXPANSION or, often, merely the COEFFICIENT OF EXPANSION. The coefficient of expansion is different for each metal and alloy. For any given material, it will also be different at different temperatures. For this reason, the coefficient of expansion given for any metal or or alloy is usually an AVERAGE coefficient for a particular temperature range. Coefficients of expansion for all commonly used metals and alloys may be found in tables given in piping handbooks, engineering handbooks, and various other handbooks.

The amount of expansion or contraction which occurs in a given length of pipe for a given temperature change can be computed by mathematical formulas. However, you can get most of the information you need from tables. The table on the next page shows the amount of expansion to be expected in various commonly used piping materials. Note that the expansion is expressed in inches per 100 feet of material at various temperatures. In this table, the thermal expansion is computed from 0 degrees F. For example, the total amount of expansion of a 100-foot length of carbon-molybdenum steel pipe that is raised from 0 degrees F to 1000 degrees F is 9.276 inches. In other words, it is 0.09276 inch per foot (9.276 divided by 100). If you want to find the amount of expansion per 100 feet for the same carbon-molybdenum steel pipe when the temperature is raised from 80 degrees F to 460 degrees F, subtract 0.580, the value shown at 80 degrees F. from 3.784, the value shown at 460 degrees F. The result is 3.204 inches. In other words, this 100-foot length of carbon-molybdenum steel pipe expands 3.204 inches when raised from 80 degrees F to 460 degrees F. It will contract the same amount when the temperature is lowered from 460 degrees F to 80 degrees F.

If piping is installed in such a way that it cannot increase or decrease in length as the temperature is increased or decreased, the piping is said to be FULLY CONSTRAINED. Tensile stresses or compressive stresses proportional to the amount of constraint are set up in piping that is partially or fully constrained. Full constraint of piping will cause tremendous stresses when the system is subjected to large temperature changes.

—Thermal Expansion of Pipe (in Inches per 100 Feet)

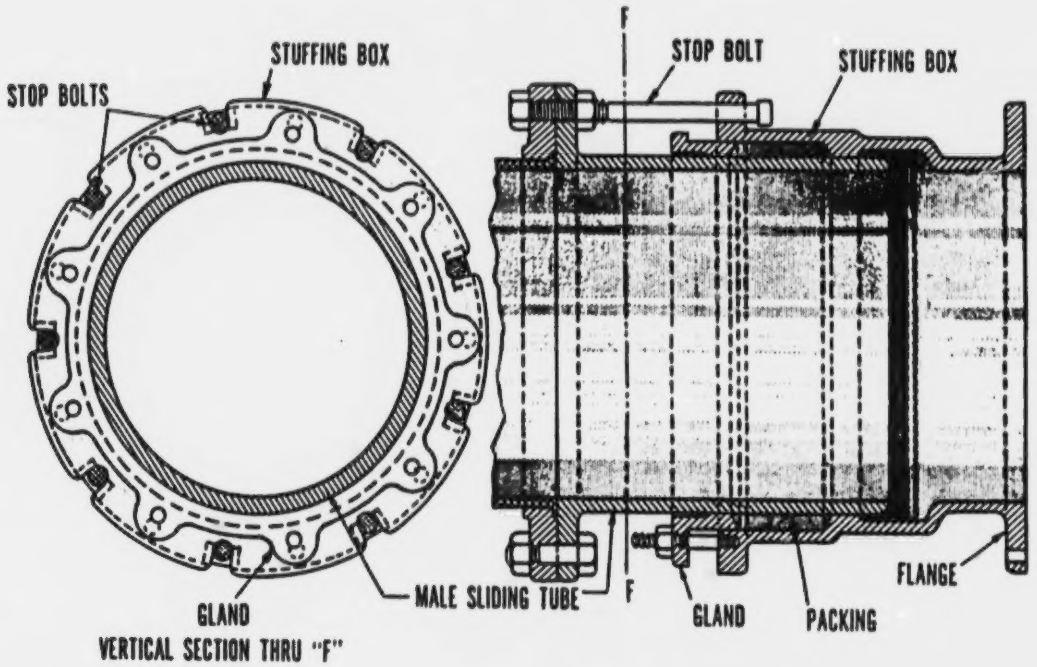
Temperature, degrees Fahrenheit	Cast iron	Carbon and carbon molybdenum steel	Wrought iron	4-6% Cr alloy steel	12% Cr stainless steel	18 Cr-8 Ni stainless steel	Copper	Brass
0	0	0	0	0	0	0	0	0
20	.128	.148	.154	.140	.140	.223	.238	.233
32	.209	.230	.249	.234	.234	.356	.366	.373
40	.263	.285	.313	.280	.280	.446	.451	.466
60	.391	.448	.468	.430	.430	.669	.684	.690
80	.522	.580	.628	.600	.600	.892	.896	.920
100	.660	.753	.787	.750	.750	1.115	1.134	1.150
120	.799	.910	.958	.900	.900	1.338	1.366	1.390
140	.924	1.064	1.113	1.050	1.050	1.545	1.590	1.625
160	1.073	1.223	1.275	1.220	1.220	1.784	1.804	1.865
180	1.218	1.383	1.445	1.370	1.370	2.000	2.051	2.100
200	1.368	1.546	1.626	1.520	1.520	2.230	2.296	2.340
212	1.451	1.643	1.721	1.600	1.600	2.361	2.428	2.467
220	1.507	1.707	1.784	1.675	1.675	2.460	2.516	2.580
240	1.653	1.875	1.958	1.825	1.825	2.680	2.756	2.830
260	1.804	2.038	2.127	2.000	2.000	2.920	2.985	3.070
280	1.958	2.205	2.313	2.150	2.150	3.130	3.218	3.315
300	2.106	2.374	2.478	2.320	2.320	3.375	3.461	3.565
320	2.268	2.545	2.648	2.470	2.470	3.615	3.696	3.820
340	2.416	2.717	2.836	2.625	2.625	3.840	3.941	4.065
360	2.573	2.884	3.023	2.820	2.780	4.075	4.176	4.320
380	2.732	3.066	3.198	2.980	2.980	4.346	4.424	4.560
400	2.881	3.230	3.369	3.140	3.130	4.560	4.666	4.825
420	3.055	3.421	3.568	3.300	3.300	4.800	4.914	5.080
440	3.218	3.595	3.748	3.470	3.470	5.045	5.154	5.340
460	3.384	3.784	3.944	3.650	3.650	5.335	5.408	5.600
480	3.556	3.955	4.128	3.800	3.800	5.540	5.651	5.925
500	3.720	4.151	4.325	4.000	4.000	5.800	5.906	6.120
520	3.893	4.342	4.525	4.150	4.150	6.050	6.148	6.380
540	4.063	4.525	4.714	4.350	4.340	6.320	6.410	6.650
560	4.238	4.715	4.905	4.540	4.500	6.572	6.646	6.920
580	4.414	4.906	5.116	4.740	4.640	6.835	6.919	7.170
600	4.598	5.102	5.303	4.920	4.850	7.100	7.184	7.440
620	4.769	5.292	5.508	5.100	5.020	7.370	7.432	7.715
640	4.955	5.482	5.698	5.280	5.180	7.630	7.689	7.980
660	5.133	5.686	5.915	5.470	5.350	7.900	7.949	8.240
680	5.315	5.875	6.108	5.670	5.550	8.170	8.196	8.515
700	5.502	6.084	6.329	5.850	5.700	8.425	8.472	8.780
720	5.681	6.280	6.521	6.050	5.900	8.670	8.708	9.050
740	5.879	6.490	6.747	6.220	6.040	8.932	8.999	9.324
760	6.073	6.688	6.948	6.430	6.280	9.220	9.256	9.600
780	6.262	6.901	7.162	6.600	6.480	9.480	9.532	9.870
800	6.460	7.105	7.356	6.800	6.680	9.750	9.788	10.150
820	6.652	7.319	7.605	7.000	6.890	10.020	10.068	10.425
840	6.843	7.517	7.800	7.200	7.090	10.270	10.308	10.690
860	7.049	7.743	8.043	7.400	7.300	10.540	10.610	10.975
880	7.248	7.953	8.248	7.580	7.500	10.820	10.971	11.250
900	7.452	8.168	8.487	7.770	7.720	11.075	11.156	11.545
920	7.668	8.400	8.715	7.970	7.950	11.350	11.421	11.815
940	7.862	8.610	8.937	8.170	8.140	11.620	11.707	12.120
960	8.073	8.830	9.148	8.360	8.350	11.900	11.976	12.420
980	8.279	9.051	9.395	8.560	8.550	12.150	12.269	12.720
1,000	8.490	9.276	9.624	8.760	8.750	12.432	12.543	13.080

The methods used to allow for expansion and contraction in piping systems fall into three general classes: (1) the use of expansion joints; (2) the use of directional changes and expansion bends; and (3) the use of an installation procedure known as "cold spring."

EXPANSION JOINTS
Expansion joints used include slip joints and various corrugated and bellows-type joints.

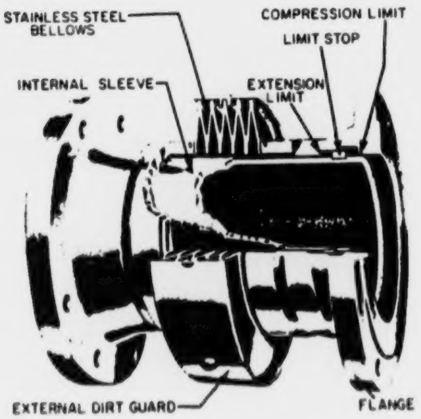
SLIP JOINTS of the type shown in the figure are used for some low pressure piping. A slip joint consists of a stuffing box, a packing gland, a male sliding tube, a female receptacle tube, and stop bolts which prevent separation of the male and female sections of the joint. The stuffing box and the male tube are flanged so that the assembly can be connected to the piping. The packing in the stuffing box is compressed by studs and nuts. The compression of the packing prevents leakage at the joint as the pipe moves in and out for a limited distance.

Slip-type expansion joints are suitable for low pressures.

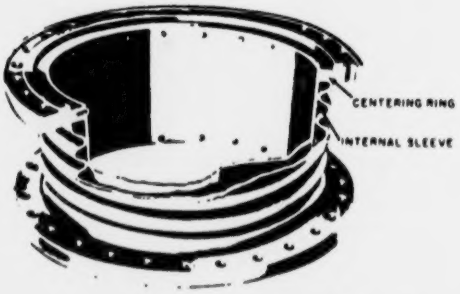

STOP BOLTS
STUFFING BOX
F
STOP BOLT
STUFFING BOX
GLAND
VERTICAL SECTION THRU "F"
MALE SLIDING TUBE
F
GLAND
PACKING
FLANGE

—Slip-type expansion joint.

CORRUGATED and BELLOWS-TYPE EXPANSION JOINTS are used for medium pressure and high pressure piping systems. A corrugated expansion joint suitable for medium pressure service is shown as is a bellows-type expansion joint that is suitable for high pressure service.


STAINLESS STEEL BELLOWS
COMPRESSION LIMIT
LIMIT STOP
INTERNAL SLEEVE
EXTENSION LIMIT
EXTERNAL DIRT GUARD
FLANGE

—Bellows-type expansion for high pressure service.


CENTERING RING
INTERNAL SLEEVE

—Corrugated-type expansion joint.

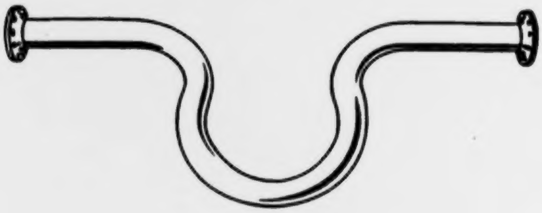
Corrugated and bellows-type expansion joints are made of various materials, including hard rubber, copper, nickel, and stainless steel. The accordian-like action of the corrugation or of the bellows allows the system to expand or contract. The movement of the pipe is absorbed by the changing curvature of the corrugations or of the bellows.

Expansion joints must be kept in effective working condition. Indicators are often fitted on expansion joints to show whether or not the joint is functioning properly. Where such indicators are not fitted, a comparison of measurements taken on an expansion joint before and after the system has reached its operating temperature will indicate clearly whether or not the expansion joint is working properly.

Expansion joint bodies must be mounted securely so that the movement is confined only to the part that is supposed to move.

EXPANSION BENDS

Loops, U-shaped bends, and offsets are fitted into piping systems so that the expansion or contraction will be absorbed by the bending in the pipe which forms the bend. Because expansion bends are more reliable and normally less expensive than expansion joints, they are preferred when conditions permit their use. The figure below illustrates a common type of expansion loop.



—Expansion loop.

Expansion bends and joints can be flexed in both directions from their normal position. They should be installed so that they are stressed in one direction when the piping is cold, and stressed in the other direction when the piping is hot. The amount and direction of the prestress or cold pull-up to be applied to piping and expansion bends or joints is indicated on the piping plans. These instructions must be followed carefully to prevent failure of the expansion joints, piping, and connected equipment.

COLD SPRING JOINTS

Another method used to provide for expansion in high pressure piping is the COLD SPRING JOINT. The pipe for this joint is cut short an amount usually equal to one half the computed expansion. After the system is fabricated and ready for installation, a dutchman (an accurately machined blank flange), equal in thickness to the required amount of cold spring, is inserted between the flanges of the cold spring joint. When all other connections have been made, the dutchman is removed and the joint set up to about 40,000 psi with temporary pull-up bolts. The temporary bolts are then replaced one by one with permanent installation bolts set up to the required bolt stress.

Reference

Hull Maintenance Technician 3 & 2, Volume 1 (NAVETRA 10571).
Washington D.C.: U.S. Government Printing Office, 1984.
(Stock Ordering No. 0502-LP-052-8630).

Properties of Metals Worksheet

1. Define load, stress, and strain.

2. If an iron bar 6 ft. long and 2 inches square in cross section is subjected to a pull of 20,000 lbs. and is stretched 0.024 in. in length, what is the load, unit stress, and strain?

3. Explain what tensile stress, compressive stress, and shear stress mean. Give an example of each.

4. What is meant by the elastic limit of a material? Give an example.

5. A certain material is so loaded that the internal stress developed in tension is 20,000 psi and that with this stress the material is strained 0.0005 inch per inch. What is the modulus of elasticity?

6. What is the amount of elongation for a material when internal stress developed in tension is 30,000 psi and the modulus of elasticity is 15,000,000 psi?

7. Explain what the ultimate strength of a material is.

8. What is the safe working strength of a material?

9. A steel bolt carries a load that induces a unit stress of 7,000 psi. What is the ultimate strength of the bolt material if a safety factor of 7 is used?

10. What is the ultimate strength of a round steel bar, 1 1/2 in. in diameter, if the steel's breaking strength is 60,000 psi?

11. Why are the principal parts of boilers subjected to internal pressure usually cylindrical in form?

12. Define hardness, toughness, plasticity, ductility and malleability in terms of metals.

Properties of Metals Worksheet Answers

1. Load is an external force acting on a body. Stress is the internal resistance that the particles composing a body offer to the action of an external load. Strain is a change of length or shape caused by an external load.

2. Load = 20,000 lbs.

   Unit Stress = load divided by area = 20,000 divided by 2 = 10,000 psi

   $$\text{Strain} = \frac{\text{increase in length}}{\text{original length}} = \frac{0.024}{72} = 0.00033 \text{ in./in.}$$

3. Tension stress refers to a pulling action on a material. Compression stress occurs within a material to oppose the forces that tend to compress or crush the material. Shearing stress occurs within a material when opposite external forces are applied along parallel lines in such a way as to tend to cut the material.

4. The greatest stress that a material is capable of withstanding without taking a permanent set.

5. 40,000,000 psi

6. .002 inch per inch

7. Ultimate strength is the maximum stress which a material is capable of withstanding in tension, compression or shear.

8. It is the maximum unit stress deemed safe for a material to carry under ordinary working conditions. It is always far less than the elastic limit, which in turn is much less than the ultimate strength.

9. Ultimate strength = working load x factor of safety
   = 7000 x 7 = 49,000 psi

10. Area of bar = 0.785 x 1.5 x 1.5 = 1.77 in. squared
    Ultimate strength = 60,000 x 1.77 = 106,200 lbs.

11. In a cylindrical vessel pressure is exerted equally in every direction on the cylindrical surface, and thus no part tends to become distorted through excessive pressure.

12. Hardness is the ability of a material to resist penetration.
    Toughness is the property that enables a material to withstand shock.
    Plasticity refers to the ability of a material to withstand extensive permanent deformation without breaking or rupturing.
    Ductility is the ability to withstand drawing out or other deformation without breaking.
    Malleability is the property that makes it possible for a material to be stamped, hammered, or rolled into thin sheets.

Reference:

Elonka, S. and Higgins, A. Standard Boiler Room Questions & Answers. New York : McGraw-Hill, 1982.

Process Piping Fabrication I Test

Multiple Choice

____1. In an experiment to show the relationship of strain to stress, different weights are used to stretch a wire until it acquires a permanent set. Which of the following statements describes the relationship of strain to stress?
  a. Strain refers to the weights used; stress is the stretching caused by the weights.
  b. Strain is the change in wire length; stress is the internal force that opposes the change.
  c. Strain is the internal force resisting the permanent set; stress is the distance the wire stretches before acquiring a permanent set.
  d. Strain refers to the total weight required to obtain the permanent set; stress is the difference between the smallest and the largest weight used.

____2. What type of stress is developed within the plate below?
  a. Shear
  b. Torsion
  c. Compression
  d. Tension

____3. What type of stress is developed within the plate below?
  a. Compression
  b. Shear
  c. Torsion
  d. Tension

____4. The tendency of a material to be cut by applied forces is classified as what type of stress?
  a. Compression
  b. Bending
  c. Torsion
  d. Shearing

In answering questions 5 and 6 refer to the following situation.

A metal bar with a cross-sectional area of 2 square inches develops an internal stress of 50,000 psi when subjected to tension. This force causes the bar to elongate 0.002 inch per inch within the elastic range.

____5. What is the amount of modulus of elasticity for the bar?
a. 10,000,000 psi
b. 15,000,000 psi
c. 20,000,000 psi
d. 25,000,000 psi

_____6. How much elongation will occur in the bar if it is subjected to an internal tension stress of 5,000 psi?
a. 0.0002 in. per in.
b. 0.0005 in. per in.
c. 0.0010 in. per in.
d. 0.0025 in. per in.

____7. A metal has failed after repeated stressing at a point although the loading is considerably lower than the ultimate strength of the metal. What term describes this condition?
a. Shear
b. Tension
c. Fatigue
d. Torsion

____8. What term describes the ability of metal to resist penetration?
a. Hardness
b. Plasticity
c. Ductility
d. Toughness

____9. What property of a material allows it to absorb a lot of energy without breaking?
a. Hardness
b. Toughness
c. Strength
d. Brittleness

____10. A weather-stripping compound that can be easily pushed into cracks around a window and can hold the shape into which it is pushed is said to have what property?
a. Plasticity
b. Creep resistance
c. Tensile strength
d. Elasticity

____11. What is the most important property for a metal that is to be drawn into a thin wire?

a. Elasticity
b. Ductility
c. Tensile strength
d. Creep resistance

____12. If you hammer a sheet of copper into the shape of a shallow bowl, you are taking advantage of what property?

a. Ductility
b. Machinability
c. Compression
d. Malleability

____13. When a metal is under constant stress, what term describes its ability to resist slow plastic deformation at high temperatures?

a. Hardness
b. Fatigue resistance
c. Creep resistance
d. Plasticity

____14. What term best describes the ease with which a metal may be planed and shaped?

a. Malleability
b. Machinability
c. Ductility
d. Plasticity

____15. You have found a set of specifications that gives the thermal conductivity rating of a metal as 23.7. The conductivity is defined in these specifications as follows: "Btu's that flow during 1 hour through a 1-inch cube when there is a 1 degree F temperature difference." Why should you be dissatisfied with the rating of the metal in question?

a. The temperature at which the test was made is not specified.
b. The standard method of measuring thermal conductivity was not used.
c. It is impossible to have a thermal conductivity rating of 23.7.
d. True thermal conductivity ratings are not normally expressed numerically.

____16. Metals which do not easily enter into chemical combinations with other metals are said to have a high resistance to which of the following conditions?

a. Wear
b. Creep
c. Corrosion
d. Penetration

____17. Which of the following expansion joints is suited for use in a high pressure steam system?
a. Corrugated type
b. Slip type
c. Bellows type
d. Corrugated or bellows type

____18. Assume that an indicator is not installed at an expansion joint in a high pressure steam system. What measurements are taken before and after the system reaches its operating temperature and then compared to determine whether the joint is functioning properly?
a. Flow rates
b. Expansion dimensions
c. Piping capacities
d. Pressure readings

Process Piping Fabrication I Test Answers

1. b
2. d
3. a
4. d
5. d
6. a
7. c
8. a
9. b
10. a
11. b
12. d
13. c
14. b
15. a
16. c
17. c
18. b

Competency:
1. Describe characteristics and applications of piping materials.
2. Describe types of joints and bonding techniques for piping materials.
3. Interpret flow properties of piping materials.

Instructional Objectives:
1. Identify the various materials from which pipe is made.
2. List applications of various materials.
3. List common methods for joining pipe.
4. State the advantages and disadvantages of threaded pipe systems.
5. State the advantages and disadvantages of welded pipe systems.
6. Explain how pipe is sized.
7. Identify common fittings used on pipe systems.
8. Identify common flanges used on pipe systems.
9. Use a flow conversion chart.

Learning Activities:
1. Read Chapters 1,2,3,4, and 13 in Pipe Fitting and Piping Handbook.
2. Complete the Piping Materials Worksheet.
3. Attend a presentation by a manufacturer's representative on fiberglass reinforced piping.

Evaluation/Checkout:
1. Submit the Properties of Materials Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Learning Materials:
1. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
2. A copy of the worksheet and answers and the test and answers is included with this unit.
3. Smith Fiberglass Products, Inc. will provide literature and a presentation on their products. Contact: Allan Schramm, District Sales Manager, Smith Fiberglass Products, Inc., 800 W. Central Road, Suite 117, Mt. Prospect, IL 60056, (312)577-0670. Contact him about 6-8 weeks in advance. His presentation includes a videotape, a demonstration of joining fiberglass pipe, and installation literature. The literature includes "Fiberglass Reinforced Piping Systems" (Bulletin 3020), "Chemical Resistance Chart" (No. 9002), "Big Thread Pipe Installation Instructions" (Manual 9500), "Grinding Tapering Tool Instructions" (Bulletin No. 9116), "General Installation Instructions" (Manual No. 9474), and "Engineering and Design Guide" (Manual 9610). For the video and literature only contact: Janice Brummett, Marketing Services Supervisor, Smith Fiberglass Products, Inc., 2700 W. 65th Street, Little Rock, AR 72209, (501)568-4010.

Resources:

1. Pamphlets:
   A. Grinnell Corporation has two excellent reference pieces available. One, "Gruvlok" (Catalog GL-84), thoroughly explains their grooved piping system. Their "Grinnell Pipe Fittings" (Catalog PF-88) provides a complete description of malleable iron, cast iron, and steel fittings. Contact: Grinnell Supply Sales Company, Technical Support/Marketing/Design Services, 1341 Elmwood Avenue, Cranston, RI 02910, (401)941-8000.

2. Audio-Visual Material:
   A. "Piping Auxiliaries 1 & 2," "Piping and Auxiliaries 1 & 2," and "Practical Shop Metallurgy" are videotapes available from NUS Training Corporation.
   B. "Joining Plastic Pipe," "Pipefitting, Bell and Spigot," "Pipefitting - Cutting/Reaming/Threading," and "Basic Pipefitting" are videotapes available from Marshall Maintenance Productions.
   C. "Rigid Products," "Rigid Pipe and Bolt Threader," "Series V Copper Tuging Tools" and "Hand Threader by Ridge Tools" are videotapes available from the National Association of Plumbing-Heating-Cooling Contractors, 180 S. Washington St., P.O. Box 6808, Falls Church, VA 22046, (800)533-7694.

Piping Materials Worksheet

1. List the principal materials from which pipe is made.

2. What is the main difference between iron and steel?

3. What is an alloy steel?

4. List an application for each of the pipe materials mentioned in the answer to question one.

5. What are the various grades of steel pipe according to ANSI specifications?

6. Explain how pipe is sized.

7. How would you determine which grade of pipe to use in a particular situation?

8. List common methods for joining pipe.

9. State the advantages and disadvantages of welded pipe systems.

10. State the advantages and disadvantages socket-welded fittings have over butt-welded fittings.

11. What is a major advantage of a flanged fitting?

12. Sketch a 90 degree elbow, a 45 degree elbow, a tee, a reducing tee, an eccentric reducer, and a concentric reducer for butt-welded, flanged, and screwed systems.

13. State the advantages and disadvantages of threaded pipe systems.

14. Sketch a welding neck flange and a slip-on-flange.

15. How are flanged joints made steam or watertight?

16. How much water is passing through a pipe having a I.D. of exactly 2 inches when the velocity of water is 5 F.P.S.? (Use chart on page 134 to answer this question).

17. What is the velocity of water in feet per second if 50 gallons per minute is flowing through a pipe with an I.D. of exactly 3 inches? (Use chart on page 134 to answer this question).

18. How much brine is passing through a pipe having a I.D. of exactly 8 inches when the velocity of the brine is 7 F.P.S.? (Use the chart on page 134 to answer this question).

19. In terms of flow of water, how many 3 inch standard wall pipes are required to equal the delivery of a 6 inch pipe under the same head? (Use chart on page 136 to answer this question).

Piping Materials Worksheet Answers

1. Wrought iron and steel, cast iron, brass and copper, lead, , aluminum, alloys, stainless steel, titanium, plastic, glass, and fiberglass.

2. Chemically pure iron is an element, or simple substance, that cannot be divided up into anything but particles of the same substance. Steel is an alloy of iron and carbon.

3. An alloy steel contains some other metal or metals in addition to carbon and iron, as chromium or nickel.

4. Wrought iron and steel - steam service
   Cast iron - water or gas service
   Brass - chemical service
   Copper - heating service
   Lead - chemical service
   Aluminum - corrosive service
   Alloy - corrosive service
   Stainless Steel - corrosive service
   Glass - chemical service
   Plastics and fiberglass - corrosive service

5. There are 10 different grades or schedules: 10,20,30,40,60,80, 100,120,140, and 160. These grades are based on pressure-stress ratios which relate the pipe dimensions directly to the maximum pressure it is intended to carry. The outside diameter is the same for each size in all schedules, but the wall thickness varies, increasing gradually from the lightest grade up to the heaviest grade.

6. To call out a pipe, it is necessary to give the schedule number and the weight/strength designation for both pipes and fittings. All pipes under 14 inches in diameter are designated by the nominal inside diameter and schedule number. Those over 14 inches are designated by the actual outside diameter and thickness of the walls. Schedule numbers from 10 through 160 are used for steel pipe. Stainless steel pipe has schedules from 55 to 80S.

7. The proper grade to use will depend upon the service for which it is intended.

8. Fittings are used to tie pipelines together. They come in screwed, welded, soldered, or flanged varieties. The majority of pipe fittings are specified by nominal pipe size, type, material, and the name of the fitting. A fitting is joined to the system by bolting, welding, or screwing.

9. Advantages: less maintenance, a permanent leak-proof bond, weighs less than the flanged type of system, easier to insulate.
Disadvantage: not easy to dismantle.

10. Advantages: the pipe does not need to be beveled, no tack welding necessary for alignment, weld material cannot extend into the pipeline, less expensive and easier to construct.
Disadvantage: possibility of a mismatch inside the fitting where erosion or corrosion could start.

11. They are easily dismantled and assembled.

12. Sketches.

13. Advantages: ease of installation, easy to dismantle.
Disadvantage: possibility of leaks, used mainly on low pressure systems.

14. Sketches.

15. This is done by placing a gasket or ring between the joint faces and tightening the flange bolts, taking care to pull them up evenly all around so that there is an equal pressure on the ring or gasket at all points.

16. 11 cu. ft. per minute
83 gal. per minute
642 lbs. of water per minute

17. 4.2 F.P.S.

18. 125 cu. ft. per minute
916 gal. per minute
9000 lbs. of brine per minute

19. 5.5

Process Piping Fabrication II Test

True of False

____1. Maintenance, durability and suitability affect the type of material chosen for a piping system.

____2. Welding is usually the best method for joining large-diameter pipe.

____3. Sealants should be used with threaded pipe.

____4. Only carbon steel pipe can be threaded.

____5. Flanges must be made of the same material as the pipe they join.

____6. Galvanized pipe is dipped into a solution of molten tin.

____7. Iron plus chromium and nickel make stainless steel.

____8. Stainless steel costs about as much as carbon steel.

____9. Aluminum pipe should be welded to retain its corrosive resisting qualities.

____10. One advantage of plastic piping systems is that they require support at less frequent intervals than metal piping systems.

____11. Chromium makes steel stainless.

____12. Stainless steel retains its strength at higher temperatures than carbon steel.

____13. Carbon steel is preferable to stainless steel at very low temperatures.

____14. Nominal size equals exact inside diameter.

____15. "L" written after a grade of stainless steel signifies low carbon content.

____16. Tees are sized by listing the dimensions straight through the tee and then listing the branch.

____17. Stainless steel lines may be connected with two carbon steel flanges if lap joint flanges are used in connection with lap joint stub ends.

____18. Flat face flange facings have no machined grooves.

____19. Lap joint flange facings have a 1/16 inch raised face.

____20. Ring joint flange facings are considered the most efficient for high pressure and high temperature service.

____21. Orifice flanges are used to meter flow.

____22. Sleeves are used over the butt welds between two straight pipes if the joint may be subjected to high external stresses.

____23. Reducers can be either concentric or eccentric.

____24. The ends of straight pipe used in socket-welded systems must be beveled before installation.

____25. In socket-welded systems, a gap of 1/16 inch must be left between the pipe and the fitting.

____26. A disadvantage of a socket-welded system is that weld metal can enter the bore.

____27. It is usually easier to align socket-welded pipe than butt-welded pipe.

____28. One disadvantage of socket-welded pipe is that the gap can trap fluids.

____29. Socket-welded pipe is used primarily on large lines, 6 inches and above.

____30. Nominal size reflects the outside diameter of pipe 14 inches and above.

____31. As schedule numbers get higher, pipe walls get thinner.

____32. 3/4-inch schedule 40 pipe has the same wall thickness as 1-inch schedule 40 pipe.

____33. "XS" pipe has thicker walls than "XXS" pipe.

____34. A union should be screwed tightly before any welding is done.

____35. A small pipe may be connected to a larger fitting by using a reducer insert.

Multiple Choice

____36. Galvanized pipe is pipe dipped into a mixture of __________ .

a. galvanic acid
b. tin
c. aluminum
d. zinc

____37. "Nominal size" is ________ .
a. a measure of wall thickness
b. an approximation of inside diameter up to 12"
c. the same as a schedule number
d. listed as STD, XS, or XXS

____38. Nominal size and actual size ___________ .
a. are always the same
b. are always given in decimals
c. usually differ
d. describe wall thickness

____39. Schedule numbers ___________ .
a. are ratios of nominal size to actual size
b. describe wall thickness
c. only apply in galvanized pipe
d. differ by manufacturer

____40. The number of threads per inch is ___________ .
a. the thread angle times two
b. pitch
c. the sum of all crests and roots
d. all of the above

Matching

____41. Full coupling

____42. Plug

____43. Close nipple

____44. Hexagon bushing

____45. Flange

____46. Lateral

____47. Elbow

____48. Union

____49. Tee

____50. Reduced Coupling

a. screws into pipe fittings to block flow.

b. makes a joint which provides easy installation and removal of valves, etc.

c. ring-shaped plate.

d. makes 45 degree or 90 degree changes of direction.

e. fully threaded male fitting.

f. joins pipes with threads of same sizes.

g. connects smaller diameter pipe to larger diameter fitting.

h. makes full 45 degree branch from main run of pipe.

i. joins pipes of different sizes.

j. makes 90 degree branch from main run of pipe.

Fill In The Blanks

__________51. Provides a right angle turn in a run of pipe along with a change in pipe diameter.

__________52. Makes a 90 degree branch from a run of pipe.

__________53. Provides a 45 degree branch to be made into a straight run of pipe.

__________54. Used over the butt welds between two straight pipes when high stress is anticipated.

__________55. A solid flange used to close off the end of a piping system.

__________56. A flange used to measure fluid flow in a system.

__________57. A flange used as an outlet for vessels, usually when severe conditions are anticipated.

For each of the following descriptions, write the correct type of flange facing.

______________58. Recessed. Both flanges of a pair are alike. Efficient for high temperature and high pressure.

______________59. One raised end, one recessed end. (Two possible answers. Choose one.)

______________60. No machined grooves.

______________61. On this type, 1/16" is usually standard for 150 and 300 pound pressure rated welding necks.

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Process Piping Fabrication II Test Answers

1. T
2. T
3. T
4. F
5. F
6. F
7. T
8. F
9. T
10. F
11. T
12. T
13. F
14. F
15. T
16. T
17. T
18. T
19. F
20. T
21. T
22. T
23. T
24. F
25. T
26. F
27. T
28. T
29. F
30. T
31. F
32. F
33. F
34. T
35. T
36. d
37. b
38. c
39. b
40. b
41. f
42. a
43. e
44. g
45. c
46. h
47. d
48. b
49. j
50. i
51. 90 degree reducing elbow
52. Tee
53. Lateral
54. Sleeves
55. Blind
56. Orifice
57. Lap joint
58. Ring joint
59. Male and female or tongue and groove
60. Flat face
61. Raised faced

Competency:

1. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe bends, linear expansion of piping, volume of tanks, and offsets.
2. Fabricate piping offsets.

Instructional Objectives:

1. Review square root, the Pythagorean Theorem, and the six trigonometric functions.
2. Solve pipe bend problems.
3. Solve linear expansion of piping problems.
4. Solve volume of tank problems.
5. Solve piping offset problems.
6. Fabricate a simple offset.
7. Fabricate a two-pipe equal spread offset.
8. Fabricate a rolling offset.

Learning Activities:

1. Read The Pipefitter's and Pipe Welders's Handbook by Frankland and complete Worksheets 1-8. The pages of Frankland that should be read are listed on the Worksheets.
2. Read Chapters 8 and 9 in Pipe Fitting and Piping Handbook.

Application Exercises:

1. Fabricate a simple offset.
2. Fabricate a two-pipe equal spread offset.
3. Fabricate a rolling offset.

Evaluation/Checkout:

1. Submit Worksheets 1-8.
2. Submit your checklist of application exercises.

Equipment:

1. These application exercises should be completed in school and on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Frankland, T., The Pipefitter's and Pipe Welder's Handbook. Mission Hills, California: Glencoe Publishing Company, 1984.
2. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
3. Copies of the worksheets and answers are included with this unit.

Resources:

1. Books
   - A. Chasis, D. Plastic Piping Systems. New York: Industrial Press, 1984.
   - B. Good Piping Practice. Troy, Michigan: Business News Publishing Company, 1983.
   - C. Hornung, W. Plumber's and Pipefitter's Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
   - D. King, R. Piping Handbook. New York: McGraw-Hill, 1967.
   - E. Frankland, T. Pipe Trades Pocket Manual. Mission Hills, California: Glencoe Publishing Co., 1969.
   - F. NAVCO Piping Datalog. Pittsburgh, Pennsylvania: National Valve and Manufacturing Company, 1974.
   - G. Matasovic, J. Universal Pipefitter's Layout Guide. New Lenox, Illinois: Universal Welding Supply Company, 1980.
   - H. Lindsey, Forrest. Pipefitter's Handbook. New York: Industrial Press, 1967.
   - I. Tinsley, R. Pipe Fabrication Layout and Offsets. Robert Tinsley Handbook, P.O. Box 1761, El Dorado, AR 71730.
   - J. Helguero, V. Piping Stress Handbook. Houston, Texas: Gulf Publishing Company, 1985.
   - K. Nolte, C. Optimum Pipe Size Selection. Houston, Texas: Gulf Publishing Company, 1978.
   - L. Gillanders, J. Pipe and Tube Bending Manual. Houston, Texas: Gulf Publishing Company, 1984.
   - M. Weaver, R. Process Piping Design, Volume 1 and 2. Houston, Texas: Gulf Publishing Company, 1973.
   - N. Sherwood, D. and Whistance, D. The Piping Guide. San Francisco, California: Syentek Books Company, Inc., 1989.
   - O. Bowman, S. Ordinates for 1000 Pipe Intersections. Baton Rouge, Louisiana: Claitor's Publishing Division, 1977.
   - P. Bowman, S. Modern Methods of Pipe Fabrication. Baton Rouge, Louisiana: Claitor's Publishing Division, 1958.
   - Q. Bowman, S. Selected Piping Problems. Baton Rouge, Louisiana: Claitor's Publishing Division, 1970.
   - R. Lee, R. Pocket Guide to Flanges, Fittings, and Piping Data. Houston, Texas: Gulf Publishing Company, 1984.
   - S. Pipe Layout for Fitters and Welders. Troy, Ohio: Hobart School of Welding Technology, 1983. This text would be excellent for apprentices that are having difficulty with layout and fabrication. It is a step-by-step, programmed instruction approach based on Frankland's books.

2. Pamphlets:
   - A. "Pipe Fitters Manual" is available from Tube Turns, Inc., P.O. Box 32160, Louisville, KY 40232.
   - B "Pipe Fitters Handbook" is available from Grinnell Supply Sales Company, Marketing/Design Service, 155 Westminister Street, Providence, RI 02903.
   - C. "Voluntary Standards for Cold Bending of Pipe" and "Voluntary Standards for Induction Bending of Pipe" are available from International Pipe Association, 5411 East State St., Rockford, IL 61108.

3. Audio-Visual Material:
   A. "Piping Familiarization" is a videotape series available from Gulf Publishing Company - Video Publishing, P.O. Box 2608, Houston, TX 77252-2608, (713)529-4301.
   B. "Advanced Pipefitting" is a series of four videotapes available from Industrial Training Corporation. Topics covered include determining pipe length, marking a pipe, cutting methods, alignment, fabricated joints, contour markers, and fiberglass reinforced plastic pipe.
   C. "Calculating Pipe Lengths" is a videotape available from Marshall Maintenance Productions.

Worksheet 1

Reference: Frankland, pp. 4-6.

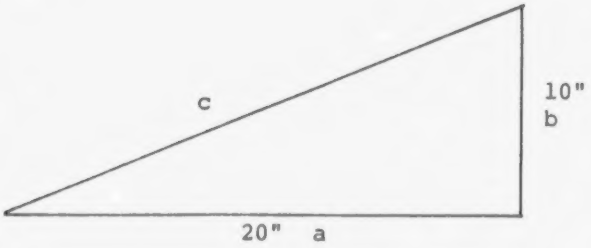
Find the square root for the following numbers.

1. 15,129
2. 68
3. 15,376
4. 250,000

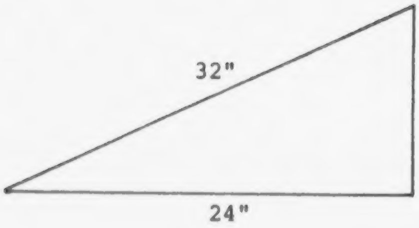
Reference: Frankland, p. 7.

Find the length of the unknown side by using the Pythagorean Theorem and square root.

5.



6.



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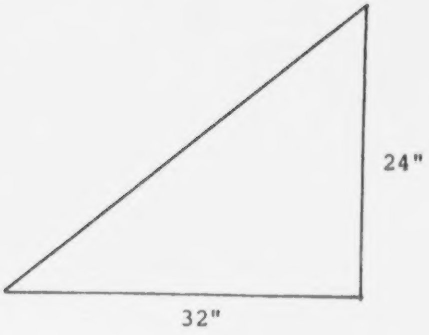

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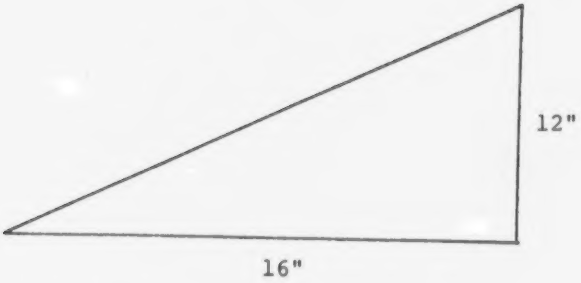


454

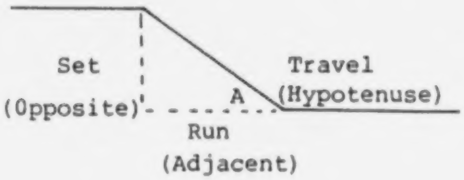
Worksheet 2

Reference: Frankland, pp. 10-13.

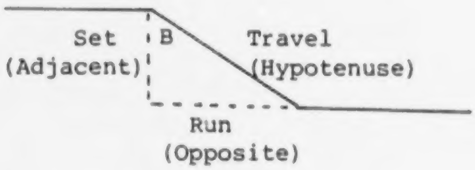
Trigonometry Review

The right angle is a 90 degree angle.
The sum of the other two angles is always 90 degrees (complementary).
The hypotenuse is always the longest side.
The side next to or adjacent to the angle is side adjacent.
The side opposite the angle is side opposite.
The labeling of the sides change with the angles.
The travel is always the hypotenuse.
The run "runs" with the pipe.
The set is the offset.

For Angle (A)


Set
(Opposite)
A
Travel
(Hypotenuse)
Run
(Adjacent)

For Angle (B)

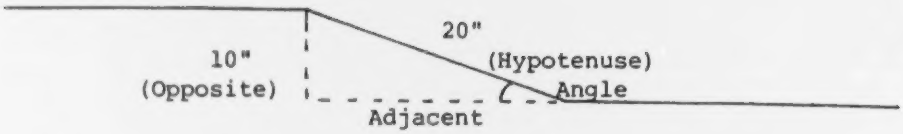

Set
(Adjacent)
B
Travel
(Hypotenuse)
Run
(Opposite)

The six functions or formulas of trigonometry are:

Sine = O/H	Reciprocal	Cosecant = H/O
Cosine = A/H	Reciprocal	Secant = H/A
Tangent = O/A	Reciprocal	Cotangent = A/O

The sine then, is the ratio of the length of side opposite to the length of the hypotenuse. By using the formula with the unknown as the numerator, the solution involves only multiplication.

EXAMPLE PROBLEM


20"
(Hypotenuse)
10"
(Opposite)
Angle
Adjacent

Sine = O/H

Sine = 10/20

Sine = .5

Angle = 30 degrees

Cosecant = .866

Secant = 1.155

Cosecant = 2

Cotangent = A/O

Cotangent = A/10

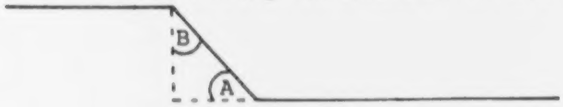
1.732 = A/10

A = 17.32"

Tangent = .577

Cotangent = 1.732

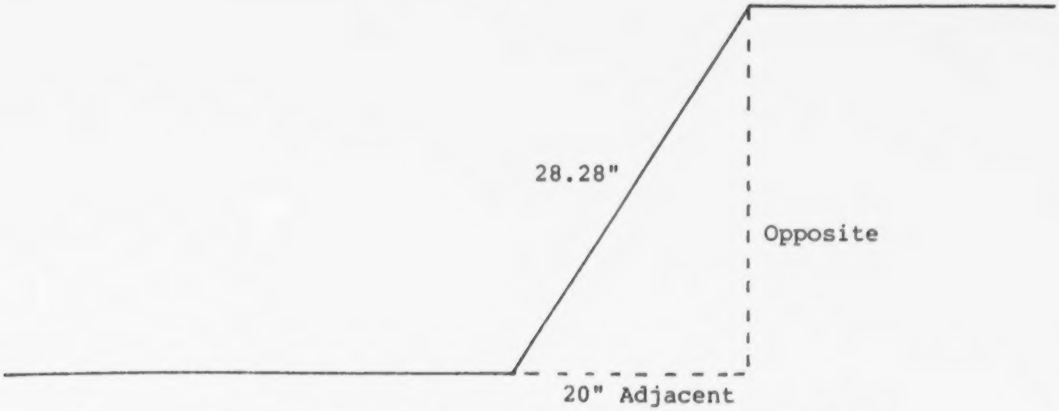
1. Fill in the missing information in the chart below.



Angle		H	A	O
A	40 degrees		12"	
B		22"	20"	
A			6"	4"
B	54 degrees	14"		
B		18"		14"
A		14.1"	10"	

Find the degree of the angle and the length of the side opposite; prove answers by working all six trigonometric functions.

2.



3. The side opposite is 20", the hypotenuse is 32-1/8". Find the degree of the angle and the side adjacent. Sketch the problem.

4. The side opposite is 10", the side adjacent is 37-5/16". Find the degree of the angle and the hypotenuse. Sketch the problem.

5. The degree of the angle is 45 degrees, the hypotenuse is 42-7/16". Find the side opposite and the side adjacent. Sketch the problem.

6. The Sine of the angle is .38268, the side opposite is 24". Find the hypotenuse, side adjacent and the degree of the angle. Sketch the problem.

Worksheet 3

Reference: Frankland, pp. 14-20.

SIMPLE BEND

1. Find the length of a piece of pipe for a 90 degree bend with a 30" radius and two 12" tangents. Sketch the problem.

2. Find the length of pipe required for a 70 degree bend with a 20" radius and two 20" tangents. Sketch the problem.

WRINKLE BEND

3. What length of pipe is required to fabricate a 90 degree wrinkle bend, with 30" outside radius, 15 degree wrinkles and two 15" tangents, also find number of wrinkles and wrinkle spacing. Sketch the problem.

SINGLE OFFSET BEND

4. Find the length of pipe required for a 25 degree single offset pipe bend, when the offset is 30", the center to face of the long leg is 50", and the radius of the bend is 30". Sketch the problem.

DOUBLE OFFSET BEND

5. Find the length of pipe required for a 35 degree double offset bend when the center to the end of the short leg is 22", the center to the end of the long leg is 32", the radius is 45.5", and the offset is 54". Sketch the problem.

EXPANSION BEND

6. Figure 12 (page 20) has the equivalent of how many 90 degree bends? Check this example problem by using 1.57 in place of .01745 per degree, and see if you get the same answer. Since 90 degree bends are the most common, the number 1.57 (90 x .01745) is the number commonly used.

Worksheet 4

Reference: Frankland, pp. 21-26.

LINEAR EXPANSION OF PIPING

The constants as used here are not actual coefficients. They are the coefficient multiplied by 100 and that product multiplied by 12 to give the answer in inches.

1. Find the expansion of 150' of steel pipe installed at 60 degrees F. with an operating temperature of 310 degrees F.

2. What is the expansion of 2" copper pipe operating 185 degrees F. and installed at 40 degrees F.? Length of copper is 200'

3. Tin has a coefficient of expansion of .0000115. What is the linear expansion of 100' subjected to a 150 degree F. temperature rise?

CAPACITIES OF TANKS

4. How many gallons will a cylindrical tank hold which is 12" in diameter and 48" in length?

5. How many gallons will the above tank installed horizontally hold when it has 4" of liquid in it?

6. Find the volume of an elliptical tank which is 2' wide, 3' high, and 3' long.

Worksheet 5

Reference: Frankland, pp. 31-42.

LAYING OUT ANGLES WITH A STEEL SQUARE

1. What is side adjacent with a 10" side opposite on a 37 degree angle? Sketch the problem and show all your work.

2. What is the degree of the angle in problem (1) if the measurement of the opposite and adjacent are turned around? Sketch the problem and show all your work.

Worksheet 6

Reference: Frankland, pp. 48-63

SIMPLE OFFSETS

The multipliers for calculating simple offsets on page 48 are the ones most commonly used in the trade. Starting on the top line, name each by the trigonometric term.

1.

2.

3.

4.

5.

6.

7. What is the length of side S for a 45 degree offset if side R is 20"? Sketch the problem. (Pages 48-49)

8. What is the length of side R for a 22 1/2 degree offset if side T is 15"? Sketch the problem. (Pages 48-49)

TWO-PIPE EQUAL-SPREAD OFFSET

Note: The constant for finding "F" is the tangent for one-half the angle of the fitting.

9. For a 30 degree two-pipe equal-spread offset with a 10" spread and a side opposite of 12", find F, D, and T. Sketch the problem. (Page 51)

10. For a 45 degree two-pipe equal-spread offset with an 8" spread and a side opposite of 15", find F, T, and D. Sketch the problem. (Page 52)

11. For a 60 degree two-pipe equal-spread offset with a 9" spread and a side opposite of 9", find F, T, and D. Sketch the problem. (Page 53)

12. For a 45 degree offset around a square obstruction, find A and F when B = 8", C = 16", D = 36", and E = 6". Sketch the problem. (Page 54)

13. For a single-pipe, 45 degree offset around a tank, find A, D, and G when B = 7", C = 10", E = 16", and F = 6". Sketch the problem. (Page 56)

14. For a two-pipe 45 degree equal-spread offset with a 90 degree turn, find A, B, and C when the spread is 8" and the side opposite is 14". Sketch the problem. (page 58)

15. For a 45 degree unequal spread offset, find H and M when A is 8", B is 6", C is 9", and D is 10". Sketch the problem. (Pages 60-61)

Worksheet 7

Reference: Frankland, pp. 64-65

TANK COILS

1. The diameter of a tank is 22' and the coil is 1' from the wall of the tank. Using 45 degree fittings, how many pieces of pipe are required and what is the length of each piece? Figure decimals of feet in inches and fractions. Sketch the problem.

2. The diameter of a tank is 25' and the coil is 18" from the wall of the tank. Using 22 1/2 degree fittings, how many pieces of pipe are required and what is the length of each piece. Figure decimals of feet in inches and fractions. Sketch the problem.

Worksheet 8

Reference: Frankland, pp. 66-69

ROLLING OFFSET

1. The roll of a 45 degree offset is 5" and has a side opposite of 12". What is the length of the travel piece? Sketch the problem.

2. The roll of a 45 degree offset is 6" and the set is 12". Find the length of the travel and run. Sketch the problem.

3. Explain how it is possible to figure a rolling offset with a square. Sketch an example.

Worksheet Answers

Worksheet 1

1. 123
2. 8.246
3. 124
4. 500
5. 22.36" or 22 3/8"
6. 21.166" or 21 3/16"
7. 40"
8. 20"

Worksheet 2

1.

Angle		H	A	O
A	40 degrees	15.66" or 15 11/16"	12"	10.07" or 10 1/16"
B	24 degrees 30'	22"	20"	9.16" or 9 3/16"
A	33 degrees 30'	7.21" or 7 3/16"	6"	4"
B	54 degrees	14"	8.23" or 8 1/4"	11.33" or 11 5/16"
B	51 degrees	18"	11.31" or 11 5/16"	14"
A	45 degrees	14.1" or 14 2/16"	10"	9.94" or 9 15/16"

2. Degree of the angle = 45 degrees
   Length of side opposite = 20"
   Sine = .70721
   Cosine = .70721
   Tangent = 1.0000
   Cotangent = 1.000
   Secant = 1.414
   Cosecant = 1.414

3. Degree of the angle = 38 degrees 30'
   Side adjacent = 25.14" or 25 1/8"

4. Degree of the angle = 15 degrees
   Hypotenuse = 38.63" or 38 5/8"

5. Side opposite = 30"
   Side adjacent = 30"

6. Hypotenuse = 62.71" or 62 11/16"
   Side Adjacent = 57.94" or 57 15/16"
   Degree of the Angle = 22 degrees 30'

Worksheet 3

1. Length of pipe = 71 1/8"
2. Length of pipe = 64 7/16"
3. Number of wrinkles = 6
   Wrinkle spacing = 7 7/8"
   Length of pipe = 77 1/8"
4. Length of pipe = 120.767" or 10.06' or 10' 3/4"
5. Length of pipe = 146.337" or 12.19' or 12' 2 1/4"
6. Six 90 degree bends

Worksheet 4

1. 3.01" or 3"
2. 3.30" or 3 5/16"
3. 2.07" or 2 1/16"
4. 23.5 gallons
5. 6.75 gallons
6. 105.75 gallons

Worksheet 5

1. 13.27" or 13 1/4"
2. 53 degrees

Worksheet 6

1. Cosecant
2. Sine
3. Cotangent
4. Tangent
5. Secant
6. Cosine
7. Length of side S = 20"
8. Length of side R = 13.86" or 13 7/8"

9. F = 2.769" or 2 11/16"
T = 24"
D = 24"

10. F = 3.31" or 3 5/16"'
T = 21.21" or 21 3/16"
D = 21.21" or 21 3/16"

11. F = 5.20" or 5 3/16"
T = 10.40" or 10 3/8"
D = 10.40" or 10 3/8"

12. A = 30.62" or 30 5/8"
F = 42.42" or 42 7/16"

13. A = 17"
D = 7.04" or 7 1/16"
G - 38.18" or 38 3/16"

14. A = 3.31" or 3 5/16"
B = 19.80" or 19 13/16"
C = 26.42" or 26 7/16"

15. H = 4.73" or 4 3/4"
M = 12.9" or 12 7/8"

Worksheet 7

1. 8 pieces of pipe
Length of each piece = 7.653' or 7' 7 3/16"
2. 16 pieces of pipe
Length of each piece = 4.292' or 4' 3 1/2"

Worksheet 8

1. Length of travel = 18.38" or 18 3/8"
2. Length of travel = 18.97" or 19"
Length of run = 13.42" or 13 7/16"
3. Pages 68-69 in Frankland

Competency:

1. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe welding layouts including miter cuts, cut lines on large pipe, tees, saddles, laterals, and elbows.
2. Use clamps and aligning devices employed in the trade.
3. Fabricate miters, tees, saddles, laterals, and elbows.

Instructional Objectives:

1. Identify pipe welding layout techniques.
2. Identify the various types of clamps and aligning devices used in the trade.
3. Use clamps to align pipe.
4. Use a level to align pipe.
5. Use a hi-lo gauge to determine alignment.
6. Use a two-hole leveler on a flange.
7. Square a flange.
8. Use a pipe flange aligner.
9. Solve miter cut problems.
10. Lay out miter cut problems.
11. Lay out and cut miters of 11 1/4, 15, 22 1/2, and 45 degrees.
12. Fabricate 2-, 3-, 4-, and 5-piece mitered elbows.
13. Solve saddle problems.
14. Layout, cut, and align saddles.
15. Solve problems dealing with tees, laterals, and Y fittings.
16. Fabricate tees, laterals, and Y fittings.
17. Use a contour marker to lay out elbows, laterals, tees, and saddles.

Learning Activities:

1. Read the Pipefitter's and Pipe Welder's Handbook by Frankland and complete Worksheets 1-6. The pages of Frankland that should be read are listed on the Worksheets.
2. Read Chapters 7 and 10 in Pipe Fitting and Piping Handbook.
3. Use Ordinates for 1000 Pipe Intersections to figure ordinates.
4. Observe as your instructor or a company representative demonstrates the procedure for using the Dearman System of pipe fit-up tools. Use the Dearman System Handbook and videotape as your guide.
5. Observe as your instructor or a company representative demonstrates the procedure for using the Contour Precision Layout and Measuring Tools from Jackson Products. Use the Contour Marker instruction booklet as your guide.

Application Exercises:

1. Demonstrate the use of internal and external line-up clamps.
2. Use a level to align pipe.
3. Demonstrate the use of a hi-lo gauge.
4. Demonstrate the use of a two-hole leveler.
5. Demonstrate how to square a flange and use a pipe flange aligner.
6. Demonstrate the use of a wrap-around.
7. Demonstrate the use of center finders.
8. Lay out ordinates on pipe.
9. Lay out and cut miters of 11 1/4, 15, 22 1/2, and 45 degrees.
10. Fabricate 2-, 3-, 4-, and 5-piece mitered elbows.
11. Lay out, cut, and align saddles.
12. Fabricate tees, laterals, and Y fittings.
13. Demonstrate the use of a contour marker to lay out elbows, laterals, and saddles.

Evaluation/Checklist:

1. Submit Worksheets 1-6.
2. Submit your checklist of application exercises.

Equipment:

1. These application exercises should be completed in school and on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.
2. Equipment necessary to demonstrate the Dearman System of pipe fit-up tools for welding. The Dearman System Catalog, Handbook, videotape, and a demonstration kit is available from: Donald Aycock, Dearman Product Manager, Dearman System, A Division of Cogsdill Tool Products, Inc., P.O. Box 900, Camden, SC 29020, (800)231-6678, (803) 438-4000. A demonstration kit is available at reduced cost (25% discount) to educational institutions. The list contains the following equipment: 1-8" Double Screw Chain Clamp, Mini-Fit Light Duty Clamp, Elliptical Hole Marker, Contour Marker, Pipefitters Square, Hold Down Clamp, 2 Hole Leveler, Hi-Lo Gauge, and a Demonstration Videotape. To arrange for a company representative to provide a demonstration, contact: Contractor's Supply and Equipment, Inc., 401 N. Perkins, St., P.O. Box 1173, Appleton, WI 54912-1173, (414) 739-2607. Ask them to arrange for the Dearman System van to visit the school. Contractor's Supply and Equipment, Inc. is the authorized distributor for the Dearman System tools for the state of Wisconsin.

3. Equipment necessary to demonstrate contour markers, layout tools, and measuring tools. The Contour Precision Layout and Measuring Tools Catalog, Contour Marker instruction booklet, and Jackson Protective Products and Welding Accessories Catalog is available from: Helen P. Basso, Marketing Coordinator, Contour Sales, A Division of Jackson Products, 5801 Safety Drive N.E., Belmont, MI 49306, (800)253-7281, (616)784-6200. To arrange for a company representative to provide a demonstration contact: Dave Dockstader, Zone Manager, (312)553-6005. Jackson Products offers a 10% discount to educational institutions through their distributors. Contact the company for the name of the nearest distributor.

Learning Materials:

1. Frankland, T., The Pipefitter's and Pipe Welder's Handbook. Mission Hills, California: Glencoe Publishing Company, 1984.
2. Bowman, S. Ordinates for 1000 Pipe Intersections. Baton Rouge, Louisiana: Claitor's Publishing Division, 1977.
3. Lamit, T. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
4. Copies of the worksheets and answers are included with this unit.

Resources:

1. A listing of books, audio-visual material, and pamphlets is detailed in Process Piping Fabrication III.

Worksheet 1

Reference: Frankland, pp. 72-84.

1. Why should a wrap-around be 3 or 4 inches wide?

2. How long should a wrap-around be in comparison to the pipe?

3. Using the method on page 74, could pipe be divided with this technique into 6 equal parts?

   8 equal parts?

   12 equal parts?

   16 equal parts?

4. You are making a 45 degree turn and one-weld with mitered pipe. What is the angle of the cut? Show work.

5. What is the angle of cut for the following mitered turns?

   a. 3-piece 60 degree turn

   b. 7-piece 180 degree turn

   c. 7-piece 90 degree turn

   d. 3-piece 90 degree turn

   e. 3-piece 30 degree turn

6. Find the length of the B section (p. 82 Frankland) for the following 90 degree turns on the given radius.

   a. 3-piece turn on a 12" radius

   b. 4-piece turn on a 30" radius

   c. 5-piece turn on a 48" radius

   d. 6-piece turn on a 60" radius

7. For a 3-piece 90 degree turn, find the angle of cut and the cutback using a 8" pipe. Also find the length of each piece for a 30" radius fitting. What would the minimum radius for a turn with pipe of this size be?

8. Determine the angle of cut for a 4-piece 90 degree turn. Also find the cutback and the length of each piece using 10" pipe with a 24" radius fitting.

9. For a 5-piece 80 degree turn using 16" pipe with a 40" radius fitting, find the angle of cut, the cutback, and the length of each piece.

10. Use a contour marker to lay out a 3-piece 90 degree turn with a 12" radius using 4" pipe. Compare this approach to Frankland's method.

Worksheet 2

Reference: Frankland, pp. 85-86.

1. Determine the length of ordinates for a 30 degree miter on a 20" pipe with 16 divisions. Also determine the cutback.

2. Compare two different methods of laying out the pipe described in question 1. Use Frankland's method and use a contour marker to lay out the pipe.

Worksheet 3

Reference: Frankland, pp. 87-94.

1. When rounding off points of a full size tee, how much should be cut off?

2. Why is the pipe beveled after the cut has been made and what is the degree of the bevel?

3. Why are center lines so important when making pipe layout?

4. Which part of the tee is beveled, the pipe or the header? Why?

5. Use two different methods to lay out a full-size tee with 4" pipe. Use Frankland's method and use a contour marker to lay out the pipe. Compare the methods.

6. Use two different methods to lay out a reducing tee with a 4" header and a 3" riser. Use Frankland's method and use a contour marker to lay out the pipe. Compare the methods.

Worksheet 4

Reference: Frankland, pp. 95-102.

1. Lay out a full size 45 degree lateral for 4" pipe two ways. Use Frankland's method and use a contour marker. Compare the methods.

2. Lay out a reducing 45 degree lateral with a 6" header and a 4" riser two ways. Use Frankland's method and use a contour marker. Compare the methods.

3. Lay out a True Y fitting with branches 45 degrees off the vertical for 4" pipe two ways. Use Frankland's method and use a contour marker. Compare the methods.

(Note: An elliptical hole marker can be used with the contour marker in making the layouts in questions 4-7).

4. Lay out a saddle for 4" pipe two ways. Use Bowman's method with ordinates and use a contour marker. Compare the methods.

5. Lay out a saddle with a 4" header and a 3" riser two ways. Use Bowman's method with ordinates and use a contour marker. Compare the methods.

6. Lay out a branch coming off at a 45 degree angle for 4" pipe two ways. Use Bowman's method with ordinates _and_ use a contour marker. Compare the methods.

7. Lay out a branch coming off at a 45 degree angle with a 6" header and a 4" riser two ways. Use Bowman's method with ordinates _and_ use a contour marker. Compare the methods.

Worksheet 5

Reference: Frankland, p. 132.

1. To fabricate a fitting from a 90 degree welding elbow, certain dimensions need to be found. Find the following dimensions for a 60 degree turn with a 4" long radius weld ell. Use the tables on pages 136 and 148 in Frankland.

A =
B =
C =
D =
E =
F =
G =

2. You measure the outside arc of a 90 degree elbow as 30-15/16" and the inside arc as 14-1/16". Using this information, figure the outside and inside arcs for a 42 degree elbow.

3. You receive a list of the following odd-angle fittings required for a particular section of piping:

A. 11-1/4 degree
B. Two 15 degree
C. Three 30 degree
D. 34 degree
E. 50 degree
F. 57 degree
G. 68 degree

Assuming that all fittings are to be made from the same nominal size of pipe, what are the fewest number of 90-degree elbows you can use?

4. To fabricate a fitting from a 90 degree elbow certain dimensions need to be found. Find the following dimensions for a 66 degree turn with a 8" long radius weld ell. Use the tables on pages 136 and 148 in Frankland.

A =
B =
C =
D =
E =
F =
G =

Worksheet 6

1. In order for a system to be correctly fabricated, alignment must be accurate. Using page 83 in Lamit as a guide, align the following using a level:

   - pipe-to-pipe.
   - 45 degree elbow-to-pipe.
   - 90 degree elbow-to-pipe.
   - Tee-to-pipe.
   - Flange-to-pipe.

2. Using the Dearman System Handbook as a guide, make the same alignments as in question one, but this time use a line-up clamp, a hi-lo gauge, a two-hole leveler, a square positioner, and/or a pipe flange aligner as necessary to make the alignments. Compare this method with the one used in question one.

Worksheet Answers

Worksheet 1

1. To keep it straight.
2. 1 1/2 times
3. No, Yes, No, Yes
4. 22 1/2 degrees
5. a. 15 degrees
   b. 15 degrees
   c. 7 1/2 degrees
   d. 22 1/2 degrees
   e. 7 1/2 degrees
6. a. 9 15/16"
   b. 16 1/16"
   c. 19 3/32"
   d. 19"
7. Angle of cut = 22 1/2 degrees
   Cutback = 1 13/16"
   A = 12 7/16"
   B = 24 14/16"
   Minimum radius = 51 3/4"
8. Angle of cut = 15 degrees
   Cutback = 1 7/16"
   A = 6 7/16"
   B = 12 14/16"
9. Angle of cut = 10 degrees
   Cutback = 1 7/16"
   A = 7 1/16"
   B = 14 1/8"
10. Instructor evaluation.

Worksheet 2

1. Cutback = 5 3/4"
   Ordinate 1 = 0
   Ordinate 2 = 2 3/16"
   Ordinate 3 = 4 1/16"
   Ordinate 4 = 5 5/16"
   Ordinate 5 = 5 3/4"
2. Instructor evaluation.

Worksheet 3

1. Two times the thickness of the pipe wall.
2. For proper alignment and fit. 45 degree angle.
3. The measurements are taken from the center lines.
4. The pipe is beveled.
5. Instructor evaluation.
6. Instructor evaluation.

Worksheet 4

1. Instructor evaluation.
2. Instructor evaluation.
3. Instructor evaluation.
4. Instructor evaluation.
5. Instructor evaluation.
6. Instructor evaluation.
7. Instructor evaluation.

Worksheet 5

1. A = 6"
   B = 3 3/4"
   C = 8 1/4"
   D = 60 degrees
   E = 3 7/8"
   F = 6 1/4"
   G = 8 5/8"
2. Outside = 14 7/16"
   Inside = 6 9/16"
3. Four
4. A = 12"
   B = 7 11/16"
   C = 16 5/16"
   D = 66 degrees
   E = 8 14/16"
   F = 13 13/16"
   G = 18 3/4"

Worksheet 6

1. Instructor evaluation.
2. Instructor evaluation.

Competency:

1. Describe the types of and operation of watertube and firetube boilers.
2. Explain the four separate systems that must function in order for a steam boiler to operate.

Instructional Objectives:

1. Describe the construction of the various high pressure boilers.
2. State ASME code concerning the difference between high pressure and low pressure boilers.
3. Identify the four separate systems of a steam boiler.
4. Explain the purpose of each of the four systems of a steam boiler.
5. Differentiate between the components of each of the four systems of a steam boiler.
6. Explain the function of the components of each of the four systems of a steam boiler.
7. Identify safety practices to be used when working with boilers and steam.
8. Draw a simple sketch of a steam system.
9. Draw a simple sketch of a feedwater system.

Learning Activities:

1. Read the Physics Review Information Sheet.
2. Read the Steam and Heat Information Sheet.
3. Read Chapters 1 and 3 and pp. 192-196 in High Pressure Boilers.
4. Read the Firetube Type Boilers Information Sheet.
5. Read the Watertube Type Boilers Information Sheet.
6. View the videotapes "Boiler Fundamentals" and "Basic Boiler Systems" (NUS Training Corporation).
7. Complete Assignment Sheet 1, "Sketch a Steam and Feedwater System."
8. Complete Assignment Sheet 2, "Inspect a Watertube Boiler."
9. Complete Tech Check 1 and Tech Check 3 in High Pressure Boilers.
10. Complete the Boiler Worksheet.

Evaluation/Checkout:

1. Submit Assignment Sheets 1 and 2.
2. Submit Tech Check 1 and 2.
3. Submit the Boiler Worksheet.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Hampden Engineering Corporation
   P. O. Box 563
   East Longmeadow, MA 01028-0563
   Contact Sheldon Shattuck
   (413) 525-3981

Hampen Engineering has a variety of trainers and simulators available.

Hampden MODEL H-185 Boiler System Trainers simulate the operating characteristics of gas-fired, oil-fired, or coal-fired steam boilers to provide students and trainees with operating experience under all conditions, both normal and abnormal.

The Basic Boiler System Trainer incorporates the following controls:

Blowdown Control
Fuel Flow
Feedwater Flow
Purge Cycle Auto/Manual
Soot Control
Air Flow
Steam Pressure
Induced Draft Fan
Forced Draft Fan

Appropriately scaled gauges indicate the following variables:

Air Flow
Blowdown Flow
Boiler Efficiency
Combustion Efficiency
Feedwater Flow
Fuel Flow
Furnace Draft
Oxygen
Stack Temperature
Steam Flow
Steam Pressure

The Industrial Process Plant Simulator is another of the many simulators available from Hampden. Designed to provide practical experience in the start up and control of a complex process. It realistically separates the "process" from the "control room." Among the physical variables measured and controlled are steam flow, steam pressure, liquid flow, liquid temperature, and liquid level.

Two liquids of different specific gravities are used so that interface level measurements may be made. A low pressure boiler provides steam for a heat exchanger. Steam flow is controlled by valve position from either pressure or temperature.

Liquid level is controlled by pump speed or valve position or both. This simulator duplicates the interaction between variables taking place in real process plants.

Learning Materials:

1. Steingress, F. and Frost, H. High Pressure Boilers. Homewood, Illinois: American Technical Publishers, 1986. An instructor's manual is available which contains the answers to the Tech Check exercises and the answers to the tests in Chapter 12. The test pages in the text are perforated and can be removed.
2. A copy of the information sheets, assignment sheets, the worksheet and answers, and test and answers is included with this unit.

Audio-Visual Material:

1. The videotapes "Boiler Fundamentals" and "Basic Boiler Systems" are available from NUS Training Corporation. They are both part of the *Pulp and Paper Operations* series.

   Boiler Fundamentals provides the principles of boiler operation, with emphasis on the basic requirements for combustion and for the production of steam. Also covered are the design and operation of water tube and fire tube boilers, the concept of heat transfer and how heat transfer occurs, and the concepts of natural circulation and forced circulation.

   Basic Boiler Systems introduces boiler systems and outlines typical air supply systems, fuel supply systems, condensate and feedwater systems, and combustion and water supply control systems. Control panel instrumentation and its use in boiler operation are also covered.

   A workbook is supplied with each unit.

Resources:

1. Books:
   A. *Operation and Maintenance Safety Manual: Accident Prevention for the Boiler Industry*. Arlington, Virginia: American Boiler Manufacturers Association, 1981. This organization has a number of publications available. Their address is: ABMA, Suite 160, 950 North Glebe Road, Arlington, VA 22205, (703) 522-7350.
   B. Elonka, S. and Higgins, A. *Standard Boiler Room Questions and Answers*. New York: McGraw-Hill, 1982.
   C. Woodruff, E., Lammers, H., and Lammers, T. *Steam Plant Operation, 5th Edition*. New York: McGraw-Hill, 1984.
   D. Langley, B. *Boiler Operations*. New York: Harcourt, Brace, Jovanovich, 1988.
   E. Steingress, F. *Low Pressure Boilers*. Homewood, Illinois: American Technical Publishers, 1986.
   F. Emerson, D. *High Pressure Boilers*. White Bear Lake, Minnesota: Minnesota Curriculum Services Center, 1987.
   G. LaRocque, L. *Boiler Operator's Dictionary*. Troy, Michigan: Business News Publishing Company, 1986.
   H. LaRocque, L. *Boilers Simplified: A Guide to Basic Boiler* Operation. Troy, Michigan: Business News Publishing Company, 1987.
   I. Jackson, J. *Steam Boiler Operation: Principles and Practice*. Englewood Cliff, New Jersey: Prentice-Hall, 1987.
   J. *Boiler Fireman's Correspondence Course*. Calgary, Alberta: Southern Alberta Institute of Technology - Power Engineering Department, 1987.

2. Audio-Visual Material:
    A. "Function of the Power Plant," "Boilers," and "Boiler Fundamentals," are videotapes available from NUS Training Corporation.
    B. "Boiler Principles I, II, III, IV" and "Boiler Operations" are videotapes available from L & K International Videotraining.
    C. "Boilers" is a videotape available from Industrial Training Corporation.

Physics Review Information Sheet

Question No. 1. What is steam?
Answer - Steam is vapor of water.

Question No. 2. At what temperature will water evaporate (boil) in the open air at sea level?
Answer - 212 Fahrenheit.

Question No. 3. If 1 cubic foot of water is evaporated at 212 degrees F. into steam at atmospheric pressure, how many cubic feet of steam will there be? In other words, what will the volume of the steam be?
Answer - 1,646 to 1.

Question No. 4. What is the relative volume of steam at atmospheric pressure, and the water from which it was evaporated at 212 degrees F.?
Answer - 1,646 to 1.

Question No. 5. What is vacuum?
Answer - The absence of all pressure in the interior of a vessel.

Question No. 6. How much pressure does the atmosphere exert upon the surface of the earth?
Answer - 14.7 pounds upon each square inch of the earth's surface.

Question No. 7. What is understood by gauge pressure?
Answer - Gauge pressure is the pressure over and above 14.7 pounds atmospheric pressure.

Question No. 8. What is absolute pressure?
Answer - Absolute pressure is the total pressure above a perfect vacuum. It equals the sum of the gauge pressure and the atmospheric pressure.

Question No. 9. How does pressure influence the boiling point of water?
Answer - The higher the pressure, the higher must the temperature of the water be raised in order to cause it to boil.

Question No. 10. In what way does pressure affect the volume of steam?
Answer - The higher the pressure, the smaller will be the volume of the steam generated from a given weight of water.

Question No. 11. In what respect should steam be considered relative to work?
Answer - As an agent through which heat performs the work.

Question No. 12. What is the most important property of steam?
Answer - Its expansive force.

Question No. 13. What law governs this expansion?
Answer - Boyle's Law of expanding gases.

Question No. 14. Define Boyle's Law.
Answer - The volume of all elastic gases is inversely proportional to their pressure.

Question No. 15. What is heat?
Answer - Heat is a form of energy which may be applied to or taken away from bodies.

Question No. 16. What is the relation of heat to matter?
Answer - All matter is charged with heat in a greater or less degree, depending upon the nature of the matter.

Question No. 17. What is the specific heat of any substance?
Answer - The ratio of the quantity of heat required to raise a given weight of that substance 1 degree in temperature to the quantity of heat required to raise the same weight of water 1 degree in temperature the water being at its maximum density, 39.1 degrees F.

Question No. 18. What is sensible heat?
Answer - Heat imparted to a body, and warming it. Sensible heat in any substance can be measured in degrees of a thermometer.

Question No. 19. What is latent heat?
Answer - Heat given to a body and while it is being added under constant pressure no temperature change is indicated.

Question No. 20. Is the heat lost that thus becomes latent?
Answer - It is not. On the contrary, it was required to produce the change in the body from the solid to liquid, or from the liquid to the gaseous state. For instance, in the transformation 1 lb. of ice into water, 144 B.T.U. of heat becomes latent, and in changing the water into steam at atmospheric pressure 970.3 B.T.U. of heat become latent.

Question No. 21. What is the first law of thermo-dynamics?
Answer - Heat and work are mutually convertible; that is, a certain amount of work will produce a certain amount of heat, and the heat thus produced will, by its disappearance rightly applied, produce a fixed amount of mechanical energy.

Question No. 22. How is heat measured with relation to work?
Answer - By the thermal unit.

Question No. 23. What is a thermal unit?
Answer - It is the quantity of heat required to raise the temperature of one pound of pure water one degree, or from 39 degrees, if temperature of greatest density, to 40 degrees F.

Question No. 24. What is the mechanical equivalent of heat?
Answer - The mechanical equivalent of heat is the energy required to raise a weight of 778 pounds one foot high, or a weight of one pound 778 feet high; in other words, 778 foot pounds. This amount of energy is stored in one thermal unit, or heat unit.

Question No. 25. In how many ways is heat transmitted?
Answer - In three ways; first by conduction; second, by radiation; and third, by convection.

Question No. 26. What is conduction of heat?
Answer - Conduction is the transmission of heat from one body to another in direct contact with it.

Question No. 27. Are all bodies equally good conductors of heat?
Answer - No. The best conductors of heat are the metals, silver, copper, tin, steel, and lead. The poorest conductors, or non-conductors, as they are termed, are hair, wool, straw, wood, liquids, and "dead" air, that is air not in circulation.

Question No. 28. What is radiation of heat?
Answer - Radiation is the transmission of heat from one body to another through an intervening space between the bodies.

Question No. 29. How is the heat in the furnace or fire-box of a boiler transmitted to the water in the boiler?
Answer - By radiation and conduction through the heating surface of the boiler.

Question No. 30. What is convection?
Answer - Convection is the transmission of heat by circulation of a fluid or gas over the surface of the hotter or the colder body.

Reference:

1. Berger, B. and Seidler, D. Stationary Steam Engineering Curriculum. White Bear Lake, Minnesota: Minnesota Curriculum Services Center, 1984.

Steam and Heat Information Sheet

Matter may be solid, liquid, or gas. In each of these states, it is composed of small particles called MOLECULES. MOLECULES are composed of ATOMS. ATOMS consist of smaller particles called ELECTRONS and PROTONS. Positive particles are called PROTONS, and negative particles are called ELECTRONS. MATTER has mass and inertia. FORCE is required to put it in motion. To change its direction of motion or its speed, or to bring it to rest when in motion, this property of matter is called INERTIA. Matter cannot be created or destroyed. Matter may be changed from one form to another. The total quantity of matter in the universe remains constant.

The unit of FORCE is the weight of a standard pound. Pressure is the force acting on a body per unit of area. ENERGY is the ability to overcome resistance. MECHANICAL ENERGY is measured in foot pounds. It may be either POTENTIAL or KINETIC ENERGY. POTENTIAL ENERGY is energy possessed by reason of position. KINETIC ENERGY is energy possessed by reason of motion. Potential and kinetic mechanical energy are interchangeable. When one form is converted into the other, the amount of energy of the second form exactly equals that of the first form.

WORK is overcoming of resistance through space. Unless there is motion, work is not performed in a mechanical sense. Work is expressed in foot pounds. WORK IN FOOT POUNDS equals FORCE IN POUNDS x DISTANCE in feet. POWER is the rate of performing work. It is equal to the amount of work performed divided by the time.

HORSEPOWER is 33,000 foot pounds per minute. HEAT is a form of energy. SENSIBLE HEAT is heat that can be measured on a thermometer. LATENT HEAT is heat that changes matter from one form to another without changing the temperature. TEMPERATURE is the measure of the intensity of heat in a body. The unit of temperature is the DEGREE. Ordinary heat may be measured by a THERMOMETER. Extremely high temperatures may be measured by PYROMETERS.

THERMOMETERS are made in the FAHRENHEIT scale. On the FAHRENHEIT thermometer, the temperature of melting ice is 32 degrees, and the temperature of boiling water is 212 degrees at atmospheric pressure at sea level. On the CENTIGRADE scale, the temperature of melting ice is zero., and the boiling point of water at atmospheric pressure at sea level is 100 degrees. Since 100 degrees centigrade equals 180 degrees Fahrenheit, one degree Fahrenheit equals five-ninths of a degree centigrade, and 1 degree centigrade equals nine-fifths of a degree Fahrenheit. To convert degrees centigrade into degrees Fahrenheit, follow the rule "DOUBLE THE NUMBER OF DEGREES CENTIGRADE, SUBTRACT ONE-TENTH OF THIS VALUE, AND ADD 32."

FAHRENHEIT DEGREES = 9/5 Centigrade degrees + 32
CENTIGRADE DEGREES = 5/9 Fahrenheit degrees - 32

There is also an "ABSOLUTE ZERO OF TEMPERATURE" or the point at which a perfect gas is considered to have ZERO VALUE. ABSOLUTE ZERO is 460 degrees below zero on the Fahrenheit scale or 273 degrees on the centigrade scale. Temperatures above 300 degrees Fahrenheit are ordinarily measured by PYROMETERS. The mercurial pyrometer is the most accurate for low temperatures. The electrical pyrometer measures high temperatures most accurately. Pyrometers are some times off as much as 40 degrees Fahrenheit. It is, therefore, wise to compare them with standard pyrometers frequently.

QUANTITY OF HEAT is measured in British Thermal Units or B.T.U. One B.T.U. will raise one pound of water 1 degree Fahrenheit from 62 degrees to 63 degrees. The SPECIFIC HEAT of a substance is the quantity of heat necessary to change the temperature of one pound of a substance 1 degree Fahrenheit. Mechanical energy and heat are mutually interchangeable. One B.T.U. equals 778 foot pounds, and one foot pound equals 1/778 B.T.U. The UNIT of mechanical horsepower is equal to 2,545 B.T.U.'s per hour, or 33,000 x 60 = 1,980.000 foot pounds per hour. Heat may be transferred in three ways, namely: CONDUCTION, CONVECTION, and RADIATION. CONDUCTION is where heat travels from a warm substance to a cold substance by contact. CONVECTION is the transmission of heat by circulation of a liquid or gas over the surface of the hotter or colder body. RADIATION is the transmission of heat through space by wave motion.

PRESSURE is measured in pounds per square inch or p.s.i. gauge. Low pressures are sometimes expressed above atmospheric pressure. Gauges showing pressures below atmosphere are called VACUUM GAUGES. Some gauges are arranged to indicate pressure below and above atmospheric pressure, and are called COMPOUND GAUGES. COMPOUND GAUGES usually are used on low pressure boilers, and read from 0 to 30 pounds p.s.i. and from 0 to 30 inches of vacuum. MANOMETERS or draft gauges are used to measure the difference in pressure between the inside and outside of a furnace or stack. The pressure at the base of a column of water is usually known as the HEAD. If the HEAD or height of a column is known, the pressure in p.s.i. gauge may be found my multiplying the height in feet by .434. If the pressure is known and one wishes to determine the height of the water column, multiply the pressure by 2.31.

Reference:

1. Berger, B. and Seidler, D. Stationary Steam Engineering Curriculum. White Bear Lake, Minnesota: Minnesota Curriculum Services Center, 1984.

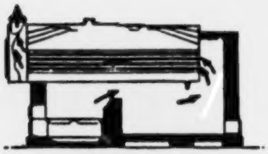
Firetube Type Boilers Information Sheet

High pressure boilers can be divided into major classifications - firetube and watertube. A firetube boiler has tubes that carry flue gases from the fluebox. The tubes are surrounded with water. As the gases travel through the firetubes, the surrounding water is heated to produce steam.

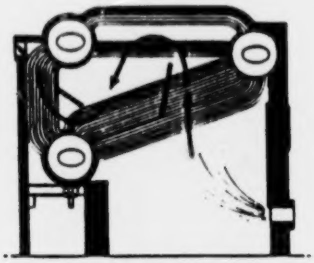
A watertube boiler circulates water through tubes instead of flue gases. Hot flue gases, outside the tubes, heat the water in the tubes and produce steam.

A steam boiler is merely a steel container in which water can be heated to produce steam. The water is heated and evaporated into steam that drives a prime mover such as the steam turbine.

The firetube boiler uses tubes to carry the heat throughout the water. Close contact between water and heated tubes makes steam production more efficient. The principle of the firetube boiler is shown in the following diagram.



Firetube Boiler

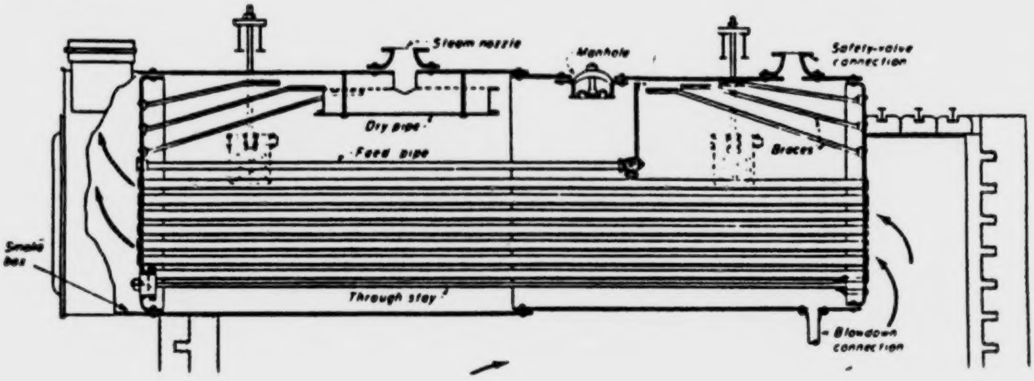


Watertube Boiler

Firetube boilers are simple in construction and low first costs make them suitable for many applications in steam generation. Many variations in design help to improve the efficiency and adaptability of the firetube boiler.

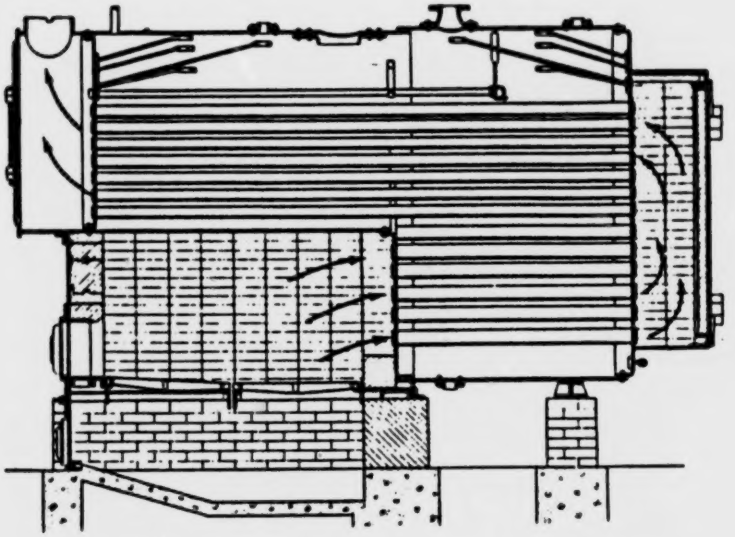
Horizontal Return Tube Boiler

A horizontal return tube boiler has firetubes running the length of the boiler shell. The top portion of the boiler is above water level and allows steam to collect. Horizontal return tube boilers can use a variety of fuels. A diagram of the horizontal return tube boiler follows.


Steam nozzle
Manhole
Safety-valve connection
Dry pipe
Feed pipe
Braces
Smoke box
Through stay
Blowdown connection

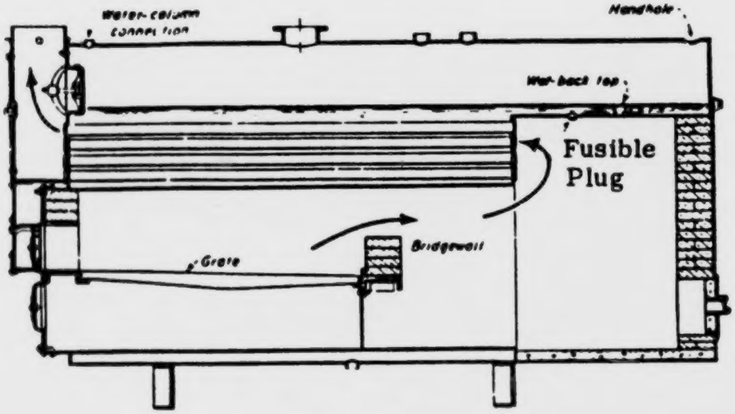
Two Pass Boilers

Two pass boilers have two sets of firetubes. The gases pass through a short set of tubes and return back through a long set of tubes. The long tubes are smaller than the short tubes.



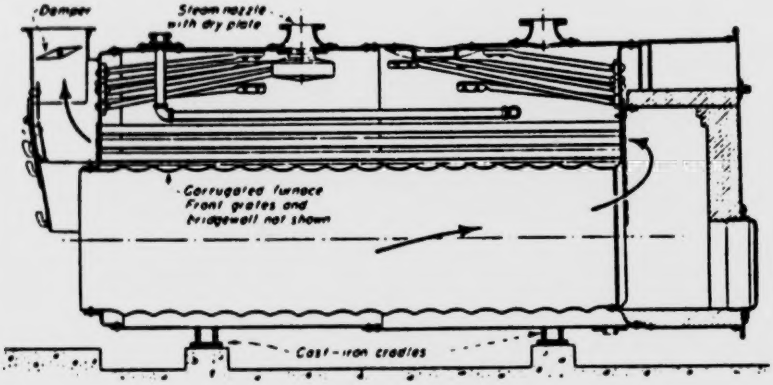
Dryback Boilers

In dryback type boilers, the furnace opens into a refractory lined chamber which causes the gases to flow back through the firetubes. The chamber is dry which gives it the name "dryback". A brick lining is used for the chamber.


Water-column connection
Handhole
Wet-back top
Fusible Plug
Bridgewall
Grate

Scotch Boilers

Scotch boilers are self-contained units with the firebox inside the boiler shell. The furnace is located below the firetubes. As gases are produced, they flow into a chamber at the end of the boiler and then pass through the firetubes to the smokebox. Such boilers are sometimes called internal furnace boilers. Scotch boilers are of welded construction with a refractory type rear chamber to send the gases back through the firetubes to the smokebox.

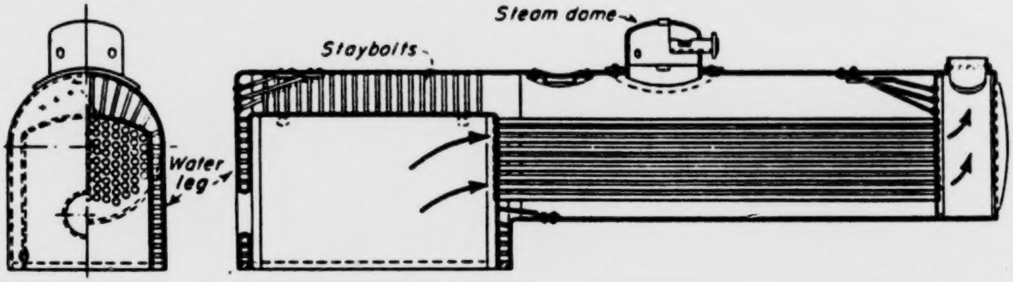

Damper
Steam nozzle with dry plate
Corrugated furnace Front grates and bridgewall not shown
Cast-iron cradles

One Pass Boilers

One pass boilers have one set of firetubes that extend much of the length of the boiler shell. Gases pass through the tubes in one direction as was shown in the horizontal return tube boiler.

Wetback Boilers

Wetback type boilers have a rear chamber that is submerged in water. This wetback design is also called a scotch marine boiler. The water that surrounds the rear chamber is called a water-leg.

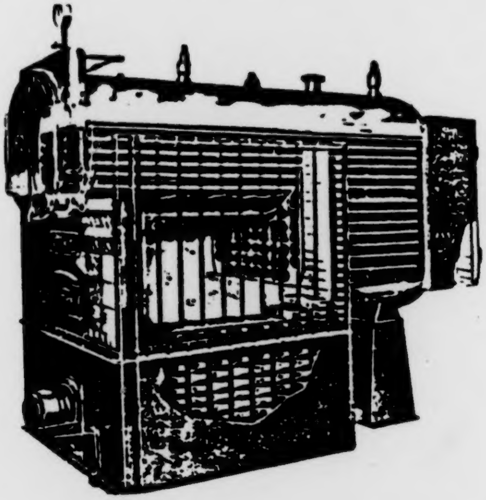


Packaged Firetube Boilers

A boiler unit that is purchased with the auxiliaries and control units intact are called "packaged" boilers. Packaged boilers can be purchased in two, three and four pass designs.

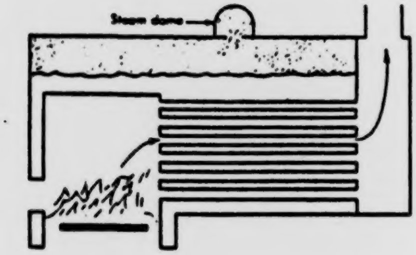
Firebox Boiler

This boiler is a low cost, efficient and compact type that is usually used as a heating boiler. The shell has two sections with two sets of firetubes. Gases travel through tubes in the lower shell section and reverse through the upper tubes. Fireboxes are encased in brick in most firebox boilers although some designs use water to surround the firebox.



Internally Fired Boilers

Designers found that the heating surface could be increased by enclosing the furnace, as well as the firetubes, inside the boiler shell. The furnace of an internally fired boiler is almost totally surrounded by water.



Shell Internals

Most boilers have cylindrical shells to resist the internal pressure of the steam. The internal shell is strengthened by the use of the diagonal stays, through bolts or tubes designed as stays. The major internal force is directed more along the length of the boiler than along its girth. A basic component of the firetube boiler is the firetubes which carry the heated gases that heat the water. The firetubes are 76 mm to 102 mm in diameter and expand at each end into tube plates. The tube plates are supported by diagonal stays or braces that attach to the boiler shell. A blow-off connection permits cleaning and draining of the boiler. Internally fired boilers have a firebox inside the shell that is surrounded by a water-leg or brick. A steam dome contains a steam outlet and safety valves. A smokebox receives the gases that emerge from the firetubes and directs them into the smoke stack for discharge from the system.

Safety Devices and Practices

The firetube boiler is much more dangerous when it explodes. Where a watertube boiler explosion is usually limited to a ruptured tube, the firetube boiler explodes completely. For safe operation of firetube boilers the operator should:

1. Make sure that the boiler conforms to ASME code in regard to materials, fabrication methods and installation of fittings.
2. Make sure that controls are responsive to changing conditions.
3. Maintain boiler in a clean condition.
4. Make periodic inspections of boiler parts.
5. Read manufacturers instructions for operation and safety of specific boiler that is being operated.

Boilers are fitted with safety valves to prevent explosions. The operator must be sure that these safety devices are functioning and that the controls are properly registering the pressures within the boilers. Damaged parts should be replaced before the boiler becomes hazardous to operate.

Reference:

1. Boiler Operators Curriculum. Eugene, Oregon: Lane Community College, 1982.

Watertube Type Boilers Information Sheet

Watertube boilers use their system of tubing to carry water instead of gases. The hot gases flow over the tubes and heat the water that is inside the tubes. Designers have improved watertube boilers during the past few years until they are very competitive with the firetube type. The need for high pressures have given the watertube boiler an advantage. A second advantage is the safety factor. Watertube boilers are not as dangerous when exploding. Normally they rupture a watertube internally rather than blowing out the entire boiler shell. The watertube boiler has greater flexibility and requires less space than firetube boilers of the same capacity.

Watertube Boilers

Watertube boilers can be divided into two types:

1. Straight tube
2. Bent tube

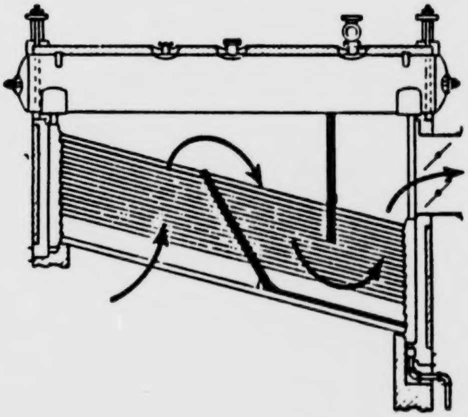
Straight tube boilers are not widely used in today's steam plants. Some old boilers of straight tube design are still in operation today but very few new ones are being made. The bent tube design has advantages that make it the popular choice. Drums are used to collect and separate water and steam. The bent tubes connect to the drums.

Packaged Watertube Boilers

A boiler that is shipped complete with fuel burning and draft equipment and automatic controls and accessories is a "packaged" boiler.

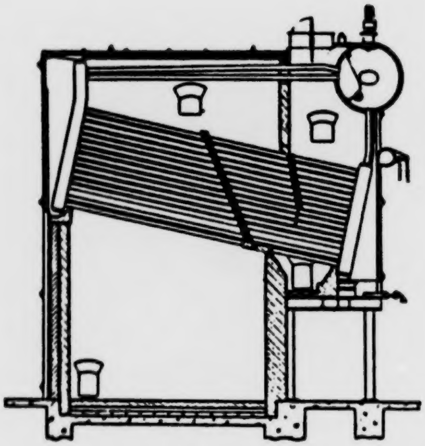
Horizontal Drum

A horizontal drum boiler is one that has a drum that is located in a horizontal plane and lies in the same direction as the straight tubes. The tubes and mud drum are connected by a tube nipple. The drum is located overhead and collects steam from the tubes.



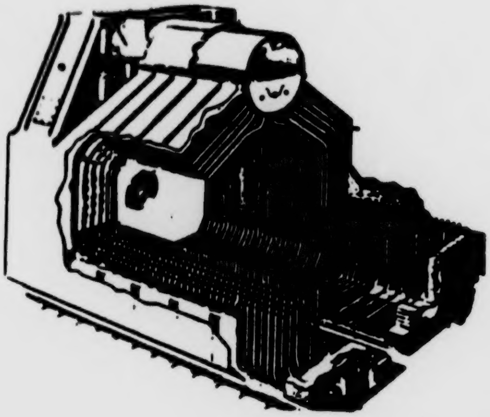
Cross Drum

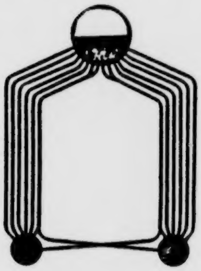
The cross drum is another configuration for straight tube boilers. The drum lies at right angles to the tubes.



Bent Tube Boilers

Bent tubes allow more surface exposure to the heat. They can be built in configurations that give a more desirable size and can usually be built cheaper than a straight tube boiler. Older boilers may have four or five drums but new models use only one or two drums. Improvements in design and fluid handling have reduced the number of drums needed in a unit. A bent type of structure shows the tubes and drums arrangement.





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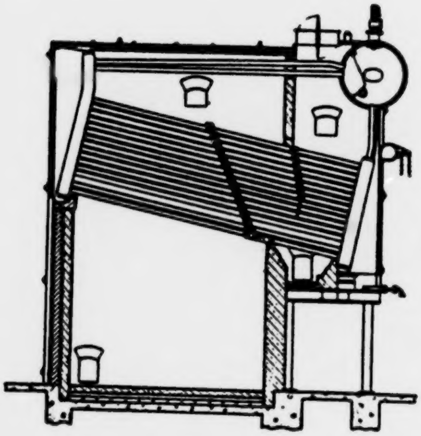
Inclined Headers

Headers are found at each end of the watertubes. These headers carry the water back to the drum. The headers can be aligned in either a vertical or inclined position in relation to the tubes and drum. Inclined headers are usually associated with a cross drum arrangement of a straight tube boiler. A header is a manifold that collects water from the tubes and carries it back to the drums.

Vertical Headers

Vertical headers are used on both cross drum and horizontal drum designs. The tubes run between vertical headers which are connected to the drum.



Box Headers

Box headers are used in some of the older straight tube boilers. A box at the bottom of a header forms the mud drum of the boiler. Each header connects to the mud drum with a tube nipple. Box headers are formed in the shape of a box.

Furnace Baffles

Baffles are used to create a flow of gases back and forth over the tubes while the water makes the needed number of passes. Baffles are made of brick, tile or other refractory material. If placed so that gases flow at right angles to the tubes, they are called cross baffles. Longitudinal baffles cause gases to flow in parallel with the tubes. Curved baffles reduce the friction which cause eddy currents.

Refractory Furnace

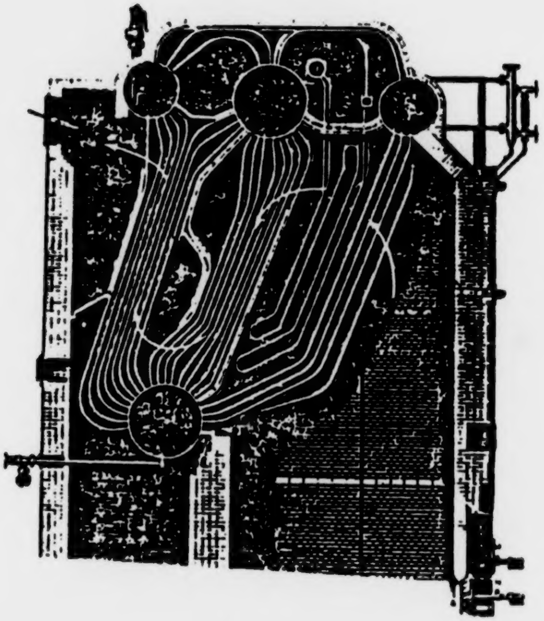
A refractory furnace is one that is lined with brick or other refractory material.

Waterwalls

Waterwalls or water legs are often used to provide a heat absorbing surface about the furnace. It serves the same purpose as brick in a refractory furnace. Almost 50% of the total furnace heat is absorbed by the waterwall. Waterwalls are also used to surround the tubes and carry steam to the top drum. As water and steam rise from the mud drum upward to the drum, convection tubes serve either as risers or downcomers. The risers carry steam upward to the drum. Downcomers carry water and steam downward to the mud drum and it is recirculated. A waterwall captures much of the furnace heat and uses it in the formation of steam.

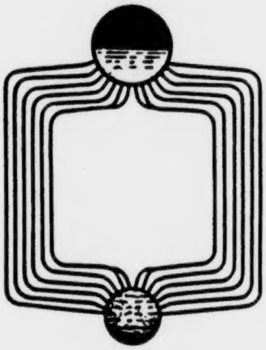
Stirling Type Boiler

The Stirling type is a four drum bent tube boiler. The boiler has three upper drums and a mud drum. The upper drums are connected to the mud drum by bent watertubes. The upper drums are partially filled with water. The drum space above the water level is used to capture steam. A steam outlet and safety valves are part of the upper drum arrangement. Also a feedwater inlet is part of the upper drum. The Stirling type boiler has a refractory type furnace. The mud drum contains water.

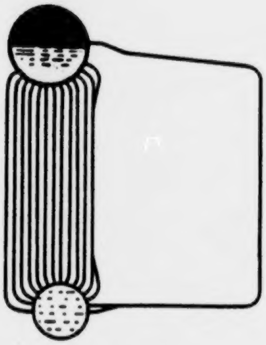


Lower Drums Headers

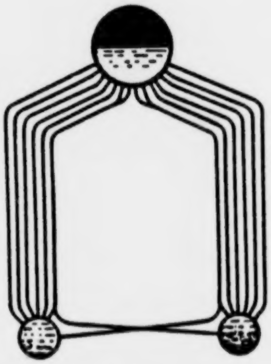
On many new models of watertube boilers, the lower drums are completely filled with water. Actually they serve as headers to direct water into the risers and collect water from the downcomers.



"O" Type



"D" Type



"A" Type

Drum Internals

Several devices are installed inside the steam drum of the boiler. Among those devices are steam separators, steam washers, chemical feed lines, boiler feedwater lines and blow-off lines. Steam separators separate the water and steam that enters the drum through the risers. Some separators use centrifugal force to separate the water from steam. Others use plates and baffles to separate the moisture. Primary separators are often of the cyclone type with a corrugated scrubber for a secondary separator. Steam washers rinse the steam between primary and secondary separations. Washing gets rid of vaporized silica which will foul turbine blades. An internal feedline distributes feedwater within the drum. A perforated pipe that distributes chemicals to prevent scale and corrosion is part of the drum internals. Blow-Off lines are of two types. A continuous blow-off line is located well below the water line and draws off sludge. A surface blow-off line is used to extract impurities at the water surface.

Safety Devices and Practices

A boiler explosion creates danger from flying parts from the steam force. When the drum ruptures, some of its water is converted to steam. The volume of water in the drum determines the force of the explosion--not pressure of the boiler. The watertube boiler is much safer than the firetube boiler in regard to explosions.

Safety valves prevent the boiler from exceeding pressures for which it was designed. Code requires that each boiler have at least one safety valve and more if the heating surface exceeds 47 square meters.

Pressure relief valves are another type of safety device. It is triggered when pressures exceed a preset level.

Each superheater is required to have at least one safety valve.

The operator can maintain a safe operation by:

1. Assuring that the boiler design conforms to ASME code for construction.
2. Following specific safety instructions of the boiler manufacturer.
3. Assuring that safety equipment and controls are responsive to changing conditions.

Reference:

1. Boiler Operators Curriculum. Eugene, Oregon: Lane Community College, 1982.

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Assignment Sheet 1

Sketch a Steam and Feedwater System

Draw two sketches, one of a steam system and one of a feedwater system. Locate and label the major components of each system.

Assignment Sheet 2

Inspect a Watertube Boiler

Examine a watertube boiler and its components and answer the following questions.

1. What is the drum arrangement?

2. Is it a straight or bent tube type?

3. Does it have headers? What type?

4. Does it have waterwalls?

5. Is the furnace lined with refractory material?

6. Where is the feedwater inlet located?

7. Where is the steam outlet located?

8. Where is the blow-off connection for boiler cleaning located?

9. Write a short description of the boiler: manufacturer, type, descriptive details.

Boiler Worksheet

1. Water and steam are collected and separated in the ______________.
2. A boiler that comes complete with automatic controls, fuel burning and draft equipment is called a ____________________ boiler.
3. A boiler that has a drum lying at right angles to the watertubes is called a ____________________ ____________________ type.
4. A ____________________ ____________________ boiler allows the watertubes more surface exposure to the heated gases.
5. A ______________________ is a manifold that collects water from the tubes and carries it back to the drum.
6. ____________________ are used to divert the flow of gases back toward the watertubes.
7. A ____________________ uses water to absorb the heat of the furnace.
8. ____________________ tubes carry steam upward to the drum.
9. ____________________ tubes carry water and steam downward to the mud drum.
10. The Stirling type boiler has a ____________________ type furnace.
11. A boiler that carries heated gases through its tubes is a ____________________ boiler.
12. Boilers with an internal firebox and a refractory type rear chamber are called ____________________ boilers or internal furnace boilers.
13. A boiler that produces steam on one trip of gases through the firetubes is a ____________________ ____________________ boiler.
14. Boilers that pass gases through a short set of tubes and then reverses the flow back through a longer set of tubes is a ____________________ ____________________ boiler.
15. A boiler that has a brick lined rear chamber is a ________________ type.
16. One that has a rear chamber surrounded by a water-leg is a ____________________ type.
17. A scotch marine boiler is a ____________________ type.
18. Boilers that are purchased complete with auxiliaries and controls are called ____________________ boilers.

19. A boiler that uses a two-section shell with short tubes in the lower section is a ____________________ boiler.

20. The ______________________ connection permits the boiler to be cleaned and drained.

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Boiler Worksheet Answers

1. Drum
2. Packaged
3. Cross drum
4. Bent tube
5. Header
6. Baffles
7. Waterwall
8. Risers
9. Downcomers
10. Refractory
11. Firetube
12. Scotch
13. One-pass
14. Two-pass
15. Dryback
16. Wetback
17. Wetback
18. Packaged
19. Firebox
20. Blow-off

Process Steam Systems I Test

Match the following terms and phrases.

1. _____ Header
2. _____ Waterwall
3. _____ Cross drum
4. _____ Bent tube
5. _____ Drum
6. _____ Stirling type
7. _____ Riser
8. _____ Downcomer
9. _____ Blow-off connection
10. _____ Steam outlet

A. Collects and separates water and steam.

B. Lies at right angle to watertubes.

C. Allows more surface exposure of tubes to heat.

D. Acts as a manifold that collects water from tubes and returns it to drums.

E. A waterfilled tube or column that surrounds the furnace area.

F. Fitting in mud drum.

G. Fitting in upper drum.

H. Carries water and steam downward.

I. A four drum bent-tube boiler with three upper drums and a mud drum.

J. Carries steam upward.

Match the following terms and phrases.

1. _____ Dry rear chamber lined with brick.
2. _____ Boiler unit purchased complete with controls and auxiliaries.
3. _____ Rear chamber surrounded by water-leg.
4. _____ Receives gases from firetubes and directs them to smokestack.
5. _____ Allows boiler to be cleaned and drained.
6. _____ Contains a steam outlet and safety valves.
7. _____ Boiler with both firetube and furnace enclosed in shell.
8. _____ Boiler has a two-section shell that contains short tubes in one section and long tubes in the other section.
9. _____ Expanded ends of a firetube.
10. _____ A container in which water is heated to produce steam.

A. Blow-off connection
B. Internally fired boiler
C. Wetback
D. Packaged
E. Steam dome
F. Dryback
G. Tube plate
H. Smokebox
I. Steam boiler
J. Firebox boiler

Process Steam Systems I Test Answers

1. D
2. E
3. B
4. C
5. A
6. I
7. J
8. H
9. F
10. G

1. F
2. D
3. C
4. H
5. A
6. E
7. B
8. J
9. G
10. I

Heat Recovery Systems Information Sheet

Heat recovery systems improve the efficiency of steam generation. The heat that is normally lost as combustion gases pass up the smokestack are conserved as heat for making steam.

The boiler has several components that are designed for recovery of heat from combustion gases. The more heat that can be recovered, the more efficient the steam generation process becomes.

Heat recovery includes superheaters that remove water from steam to make it more efficient. Reheaters serve as superheaters for steam that is returned from the turbine. Economizers absorb heat from the combustion gases into tubes filled with feedwater. Air heaters absorb the combustion gas heat into the air that will be returned to the furnace. All of these components are designed to improve the efficiency of modern boilers.

Superheaters and Reheaters

The superheater and reheater are designed to increase the temperature of steam. Both are made up of tubes over which the furnace gases can pass. Regular boiler steam contains moisture and is called saturated steam. If this steam has the moisture removed by passing it over a superheater, it becomes dry steam with increased temperature. Dry steam produces more energy than saturated steam. After steam enters the turbine and expands, it cools and the temperature drops. The steam is returned to the boiler for reheating. A reheater is actually a type of superheater.

Superheaters are of two types:

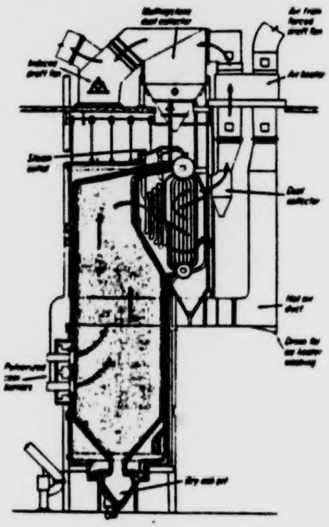
1. Integral type
2. Separately fired type

Integral Type Superheaters

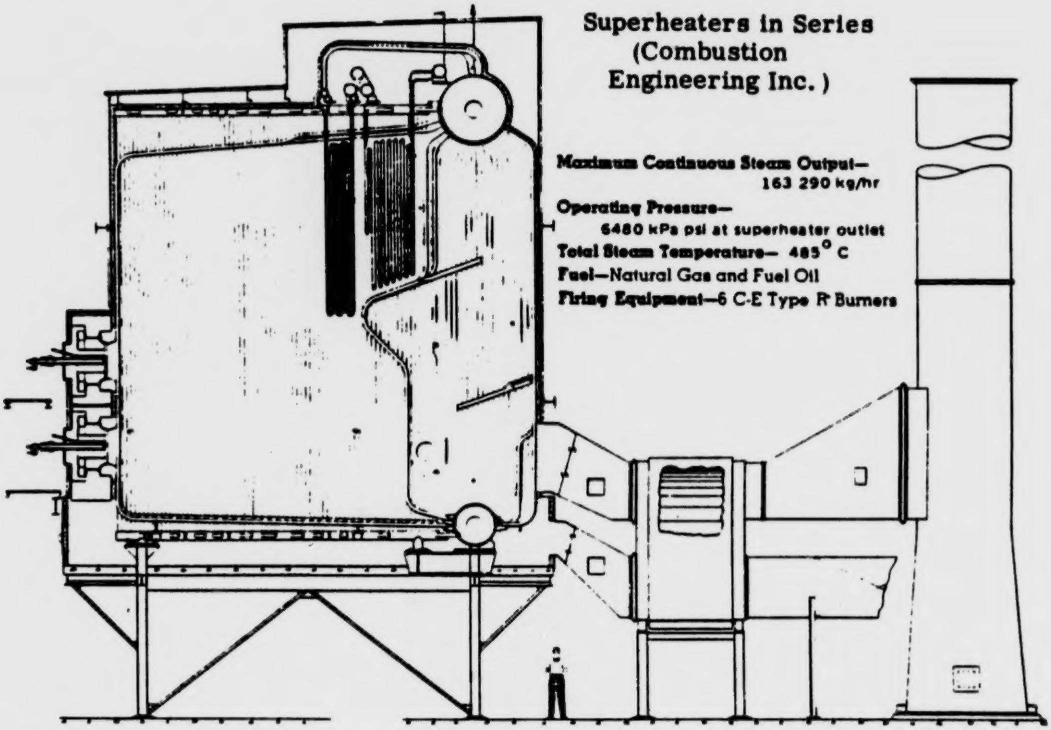
Integral type superheaters may be further classified into:

1. Convection superheater that is shielded from the radiant heat of the furnace.
2. Radiant superheater that is exposed to the radiant heat of the furnace.
3. Combination superheater that is partly exposed and partly shielded.

A convection type superheater is shown below.


Air from forced draft fan
Induced draft fan
Air heater
Steam outlet
Dust collector
Hot air duct
Pulverized coal burners
Dry ash pit

A combination superheater is shown in the following illustration.



Superheaters in Series (Combustion Engineering Inc.)

Maximum Continuous Steam Output—
163 290 kg/hr

Operating Pressure—
6480 kPa psi at superheater outlet

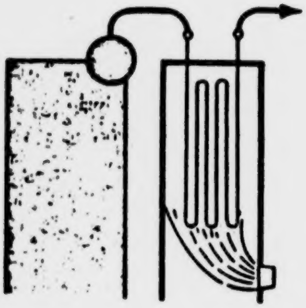
Total Steam Temperature— 485° C

Fuel—Natural Gas and Fuel Oil

Firing Equipment—6 C-E Type R Burners

Separately Fired Superheaters

A separately fired superheater has its own furnace. It is housed separately from the steam furnace. It may be supplied with steam from several units. The greatest disadvantage to this type of superheater is the cost. The principle of a separately fired superheater is shown in this diagram.

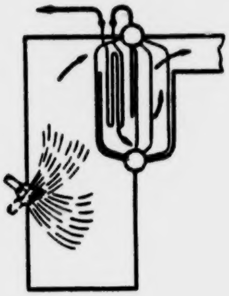


One adaptation of the separately fired superheater is the twin furnace. It consists of two furnaces in one unit. Superheater tubes are placed in one furnace and the steam from both pass through it.

Steam Temperature Control

Several methods are used to control the temperature of steam leaving the superheater. For efficient turbine operation, the temperature of its steam supply must remain constant.

- Tilting Burners have burners that can be tilted up or down. If temperature is too high, the burners are tilted downward. If too low, they are tilted upward.



- Twin Furnace used on separately fired superheaters.

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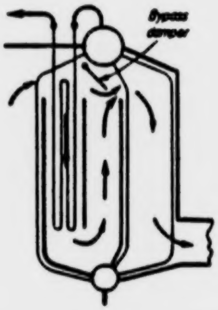
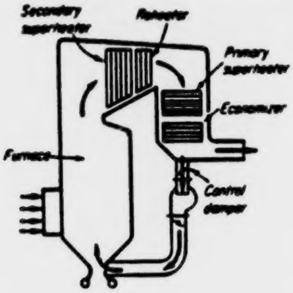
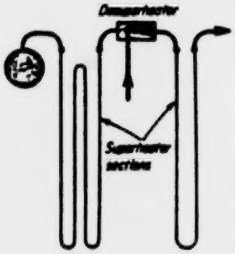
- Combustion Gas Bypass routes some of the combustion gases around the superheater to avoid overly high temperatures.


Bypass damper

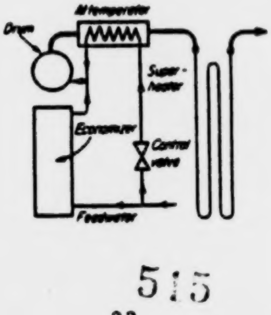
- Combustion Gas Recirculation recirculates combustion gas over the superheater tubes to raise temperature.


Secondary superheater
Reheater
Primary superheater
Economizer
Furnace
Control damper

- Desuperheating lowers temperature by spraying feedwater into the superheated steam.


Desuperheater
Superheater sections

- Attemperation lowers the steam temperature by condensing it as it passes over the attemperator tubes which are filled with feedwater.


Attemperator
Drum
Super-heater
Economizer
Control valve
Feedwater

Economizers

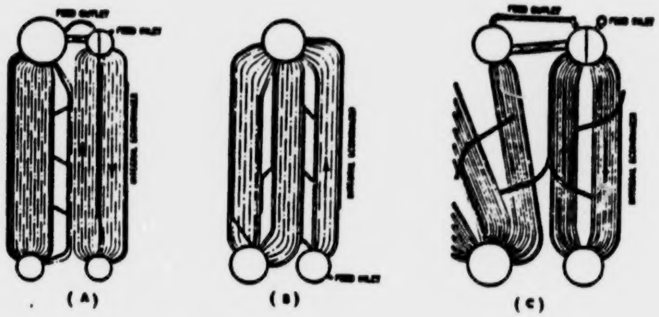
Economizers are also a series of tubes. They are designed to absorb heat from combustion gases. This savings of heat will improve the economics of steam generation. Economizers are of two basic types:

1. Integral economizer is one that forms an integral part of the boiler.

2. Separate economizer is located outside of the boiler. This type is the most commonly used economizer.

Integral Economizer

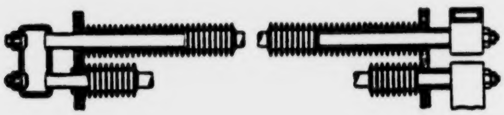
The integral economizer is a tube and drum arrangement. The tubes may attach to the drum of the boiler or may have two drums of its own. Some typical integral economizer arrangements are shown.



Separate Economizer

Separate economizers are located outside the boiler. They consist of rows of tubes placed horizontally. The tubes are filled with feedwater. As combustion gases flow over the tubes, the feedwater collects heat from the gases. Economizers are available in different configurations.

- Extended surface tubes have straight tubes with cast iron fins that provides more surface for heat collection.



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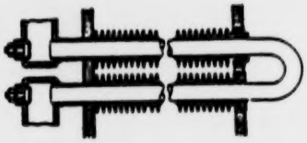
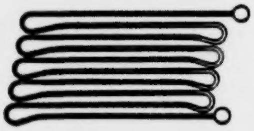
- U-bend tubes has extended surface u-bend tubes.



- Continuous tube has a continuous tube that loops between headers.



Air Heaters

Air heaters are used to collect heat from the flue gases. It can be used in addition to the economizer. The air heater is a heat exchange surface that is located in the flow of combustion gases. The air absorbs the heat where in an economizer the heat was absorbed by feedwater in the tubes. Heated air is then used in the combustion process. Combustion efficiency is improved with increases in the temperature of the air that enters the furnace. Air heaters are of two basic types:

1. Recuperative heaters
2. Regenerative heaters

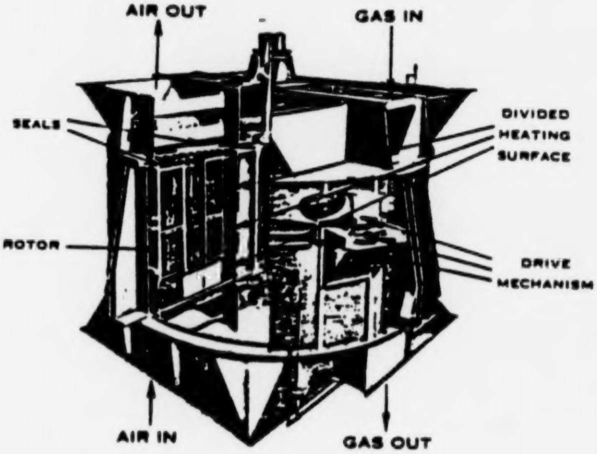
Recuperative Air Heaters

The heat from the gases is transferred through the wall of a tube or plate to the air on the other side. Recuperative air heaters may be further classified into two types.

1. Plate air heaters consist of a series of thin plates with passageways between them. Flue gases pass through every other passage and air passes in the alternate spaces. The gases and air flow in opposite directions. Heat is passed through the plates.
2. Tubular air heaters have a series of tubes that carry air to the combustion chamber. Flue gases pass over the tubes and heat is transferred through the tube wall to the air inside. Tubular heaters may be arranged horizontally or vertically.

Regenerative Air Heaters

In regenerative air heaters, metal sheets are heated by the gases and then moved to heat the air at another location. It becomes a second hand heating process as compared to recuperative type heaters. The most common type is the rotary regenerative air heater. The rotor turns slowly and the metal plates are heated by the gases. As it continues to turn, it passes through the air section and gives up its heat. A rotary regenerative air heater is pictured below.



Reference:

1. Boiler Operators Curriculum. Eugene, Oregon: Lane Community College, 1982.

Competency:

1. Explain the purpose of the steam boiler fittings that are required to operate the boiler safely and efficiently.
2. Describe the steam boiler accessories that are necessary for its safe and efficient operation.
3. Demonstrate the ability to install steam boiler fittings and accessories.

Instructional Objectives:

1. Describe the purpose and operation of safety valves.
2. Explain the reasons a water column is used on a steam boiler.
3. Describe the functions the gauge glass, try cocks, and alarm whistles have on a steam boiler.
4. Identify the types of pressure gauges used on a steam boiler.
5. List the reasons boiler vents and steam separators are used on a steam boiler.
6. Explain the function of superheaters, economizers, and air heaters in a steam system.
7. List the purpose of a sootblower.
8. Describe the proper valve type to use for given boiler piping situations.
9. Detail the proper installation of a safety valve, water column, and pressure gauge on a steam boiler system.
10. Install a safety valve on a steam boiler system.
11. Install a water column on a steam boiler system.
12. Install a stop valve on a steam boiler system.
13. Install a blowdown valve on a steam boiler system.
14. Install a swing check valve in the feedwater line of a steam boiler system.
15. Differentiate between blowdown and flash tanks.
16. Describe the components of the heat recovery system for a steam boiler.

Learning Activities:

1. Read Chapter 2 in High Pressure Boilers.
2. Read pp. 495-518 in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Boiler Fittings" - Lecture 4 in the Boiler Fireman's Course.
3. Read the Heat Recovery Systems Information Sheet.
4. Read "Piping Pointers" and "Choosing the Right Valve" from Crane Company.
5. View the videotape "Boiler Operation, Waterside" (Marshall Maintenance).
6. Complete Tech Check 2 in High Pressure Boilers.
7. Complete the Steam Boiler Fittings and Accessories Worksheet.

Application Exercises:

1. Install a safety valve on a steam boiler system.
2. Install a water column on a steam boiler system.
3. Install a stop valve on a steam boiler system.
4. Install a blowdown valve on a steam boiler system.
5. Install a swing check valve in the feedwater line of a steam boiler system.

Evaluation/Checkout:

1. Submit the Tech Check 2.
2. Submit the Steam Boiler Fittings and Accessories Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on-the-job. A list of the application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Steingress, F. and Frost, H. *High Pressure Boilers*. Homewood, Illinois: American Technical Publishers, 1986. An instructor's manual is available which contains the answers to the Tech Check exercises and the answers to the tests in Chapter 12. The test pages in the text are perforated and can be removed.
2. Brumbaugh, J. *Heating, Ventilating, and Air Conditioning Library - Volume I*. New York: Macmillan Publishing Company, 1986.
3. *Boiler Fireman's Course*. Calgary, Alberta: Southern Alberta Institute of Technology, 1987.
4. A copy of the information sheet, worksheet and answers and test and answers is included with this unit.
5. "Piping Pointers" (VC 1013A) and "Choosing the Right Valve" (VC 1012B) are available from: Crane Company, Valve Division, 800 3rd Avenue, King of Prussia, PA 19406, Attn: Kim Weber, (215) 265-5050. Crane also has available an index of Crane Valves which the instructor may find useful.

Audio-Visual Material:

1. The videotape "Boiler Operation, Waterside" is available from Marshall Maintenance Productions. The tape shows the operation procedures of the steam and water controls on a packaged steam boiler.

Resources:

1. Books:
   - A. Mead, J. *Valve Selection and Service Guide*. Troy, Michigan: Business News Publishing Company, 1986.
   - B. A listing of other books is detailed in Process Steam System I.

2. Pamphlets:
   A. "Handbook of Valve Information - Powell Valves" (Form 321), The Wm. Powell Company, 2503-31 Spring Grove Avenue, P. O. Box 14006, Cincinnati, OH 45214, (513) 852-2000.
   B. "Float Operated Valves and Switches" (Bulletin SL-SA), McDonnell and Miller, ITT Corporation, 3500 N. Spaulding Avenue Chicago, IL 60618, (312) 267-1600.

3. Audio-Visual Material
   A. "Reading System Diagrams," "Steam Systems," "Condenser, Circulating Water, and Fire Protection Systems," "Condensate and Feedwater System," "Boiler Operations," "Sootblower Maintenance," "Gauge Glass Maintenance," and "Safety Valves 1 & 2" are videotapes available from NUS Training Corporation.
   B. "Boiler and Boiler Equipment" is a videotape available from Industrial Training Corporation.

Steam Boiler Fittings and Accessories Worksheet

A. 1. Make a sketch of a directly attached gauge glass.

2. Describe the principle of operation of the Bourdon tube steam gauge.

3. What is the purpose of a safety valve?

4. What causes the safety valve to stay open until the boiler pressure drops below popping pressure?

5. List three ill effects when steam is allowed to enter a Bourdon tube gauge.

6. List how a steam gauge should be installed.

7. How would you determine if a water gauge is properly set?

8. How is the pipe connected to the discharge of a safety valve?

9. A steam gauge is 30 feet below a steam line on a 100 psi system. What will the gauge read?

10. The safety valve is 4 inches in diameter and the boiler pressure is 450 psi. What is the total pressure on the valve?

B. Indicate what type of fitting is listed below by inserting the proper letter in the blank beside the number.

_____ 1. Single nozzle retractable type

_____ 2. Globe type

_____ 3. Seatless sliding plunger type valve

_____ 4. Bourdon spring gauge

_____ 5. Screw and yoke type gauge

_____ 6. Nozzle reaction type

_____ 7. Steam washer

_____ 8. Flat glass gauge

_____ 9. Fireside type

_____ 10. Regulating valve

A. Safety valve

B. Water column or gauge glass

C. Pressure gauge

D. Feedwater connection or valve

E. Blow-off connection or valve

F. Stop or check valve

G. Drum internal

H. Soot blower

I. Fusible plug

J. Non-return stop valve

C. 1. Define the following types of valves:

A. WSP
B. IBBM
C. NRS
D. CS

2. What type of valve must be used first coming from the boiler and going to the feedwater pump?

3. Where should a feedwater line be installed on the boiler?

4. When 2 or more power boilers are fed from the same feedwater line, what type of valve must be used on each boiler?

5. Name the valve that keeps its stem screw isolated from the fluid and you can see when it is open or closed by the stem.

6. The second valve from the boiler to the feedwater pump must be a ____________________ valve.

7. What type of valve is installed with the pressure below the disc and is used for steam throttling? Why?

8. Name two types of boiler blowdowns.
A.

B.

9. Name the valve that is first from the boiler on a bottom of a boiler blowdown.

10. What accessories are needed on a blowdown line before it can be run into a sewer?

D. 1. What is the purpose of the stop valve or the stop-check valve on the boiler steam supply line?

2. What are some of the advantages of the OS&Y rising stem valve compared to other designs?

3. What is a stop-check valve?

4. If the stop-check valve is used and there are three boilers feeding into a header, how many stop valves would be needed? How many stop-check valves and why?

5. What type of valves should be used on the drains from the stop valves? Why?

6. How is a globe valve installed in a steam line?

7. What is a dashpot?

8. What are the "bosses" used for that are cast in the gate stop valve?

E. Match the following terms with the phrases by writing the proper letters into the blanks beside the numbers.

_____ 1. Economizers

_____ 2. Reheaters

_____ 3. Convection type superheater

_____ 4. Saturated steam

_____ 5. Separately fired superheater

_____ 6. Dry steam

_____ 7. Radiant superheater

_____ 8. Tilting burners

_____ 9. Combination superheater

_____ 10. Recuperative

A. Exposed to the radiant heat of the furnace.

B. Steam with moisture removed by superheating.

C. Partially exposed and partially shielded from the radiant heat of the furnace.

D. Reheats steam that is returned from the turbine.

E. Absorbs heat from combustion gases into feedwater filled tubes.

F. Shielded from radiant heat of the furnace.

G. Type of air heater.

H. Steam that contains moisture.

I. Method for controlling temperature of steam that leaves the superheater.

J. Superheater has its own furnace separate from the steam generation furnace.

Steam Boiler Fittings and Accessories Worksheet Answers

A. 1. See Text.

2. See Text.

3. When the pressure in the boiler reaches a certain point, the safety valve will open and release steam to the atmosphere, thus preventing any further increase in pressure.

4. A safety valve has a disc with two areas, closing on a single seat, the lower area of the disc protruding through the seat. The lower one is smaller so once the valve is open, the pressure is working on the bigger area of the disc. This causes the valve to "pop" open and to close at a lower pressure.

5. Linkage will expand due to the heat of the steam. The elasticity of the tube will be affected. High temperature will affect the soldered tip of the tube and the other soldered parts.

6. When installing a gauge, use a steam siphon and fill the siphon with water first. Use a valve on the top of the siphon and keep the gauge level and true.

7. When 3" or more of water is over the tubes or crown sheet in the boiler and it shows in the bottom part of the gauge glass, then the water gauge is properly set.

8. With a discharge elbow and drip pan unit. The nipple used should be as short as possible.

9. 30' x .433 psi/ft. = 12.99 psi. or 13 psi.
100 psi line
+ 13 psi to gauge
113 psi at gauge

10. A = 3.14 x Rad sq.
A = 3.14 x (2") sq.
A = 12.56 in. sq.

TF = A x P
TF = 12.56 in. sq. x 450 psi
TF = 5,652 lbs.

B. 1. H

2. J

3. E

4. C

5. F

6. A

7. G

8. B

9. I

10. D

C. 1. A. working steam pressure
B. iron body bronze mounted
C. non-rising stem
D. cast steel

2. Stop valve.

3. Where the feedwater is pre-heated before it comes into the boiler without directly coming in against surfaces exposed to hot combustion from the fire.

4. Globe or regulating valve on each boiler before the check valve.

5. OS&Y gate valve.

6. Check valve.

7. Globe valve with plug type seat and disc. The water could still get into the boiler if the disc would come off.

8. Bottom and surface blowdowns.

9. Quick open valve.

10. A blowdown tank where the water temperature is not higher than 140 degrees F. and the pressure is less than 5 psi. before the water from the boiler blowdown is run to the sewer.

D. 1. The main stop valve is usually a nonreturn globe type valve and it is designed to prevent backflow of steam into the boiler when two or more boilers are used. When the pressure in the boiler falls below the steam main pressure the valve will close automatically and stay closed until the pressure in the boiler is greater than the steam header.

2.
   1. The rising stem makes it apparent from a distance whether the valve is open or closed.
   2. The stem threads are protected from the steam and scale.
   3. Easy to grease the stem threads and to repack the valve.

3. A valve of a globe design with the disc free of the stem so that when the stem is out, the pressure below the disc is greater than the pressure above the disc and the valve will open. When the pressure is less below the disc, the valve will close. The valve can be opened or closed by the hand wheel like a standard valve.

4.
   A. six
   B. three stop-check valves. The stop-check valves would be next to the boilers and regular stop valves would be next to the header.

5. OS&Y type of gate valves so that when they are open the operator can tell at a distance. When working on or in a boiler the worker can tell if the main stop valve is holding closed by whether the free drain is leaking condensate or not.

6. It is normal practice to install globe valves with the pressure below the seat. On a boiler this allows for repacking the valve while it is under pressure by closing the valve before packing. There are times when high pressure steam should be above the seat. The valve will automatically close if the disc should come off of the stem. This is a safety feature.

7. The dashpot is a chamber, like a cylinder wall, where two pistons or discs run up and down due to pressure differences. The dashpot is used in stop-check valves.

8. To drill and tap for installing a bypass on stop valves. Can also be used for installing a free drain on a stop valve.

E. 1. E

2. D

3. F

4. H

5. J

6. B

7. A

8. I

9. C

10. G

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Process Steam Systems II - Test 1

1. How is the size and number of safety valves determined?

2. What controls might you find on a water column?

3. What is the most important valve on the boiler?

4. Would you ever find automatic shut-off valves on a water column?

5. How high above the top row of tubes should the lowest try cock be placed?

6. Is the top gauge glass valve different than the bottom valve?

7. Identify the following abbreviations of valves.

   A. SP
   B. SS
   C. OS&Y
   D. AI
   E. RS
   F. WOG

8. Why must the feedwater be preheated before it comes into the boiler?

9. What two valves must each power boiler have on the feedwater line near the boiler? Which valve is closest to the boiler?

10. What is a steam stop valve?

11. Why is an OS&Y valve used?

12. What is the best type of globe valve for steam throttling? Why?

13. What are three things that a bottom blowoff can be used for?

14. Describe a slow-opening valve.

15. Explain how a stop-check valve prevents back-flow.

16. What is a steam cock? What valve is now replacing the steam cock in many jobs?

True or False

17. _____ A power operated relief valve is a type of safety valve.

18. _____ Gauge glasses are used to determine the color of boiler water.

19. _____ Tubular gauge glasses are needed on boilers with operating pressures above 2800 kPa.

20. _____ Pressure gauges must show a range of 1 1/2 times the allowable working pressure to meet code.

21. _____ A bellows gauge is a type of pressure gauge.

22. _____ The Bourdon spring gauge operates from pressure on a C-shaped tube that causes it to straighten out and open the valve.

23. _____ The outside screw-and-yoke valve is the most common type of safety valve used on boilers.

24. _____ There are two major kinds of blow-off connections on boilers.

25. _____ A steam separator is one of the drum internals.

26. _____ Natural gas burners require several soot blowers to free the heating surface of ash.

Fill in the Blanks.

27. U-bend tubes are often found in _____________________.

28. An _________________________ economizer is formed as a part of the boiler.

29. ______________________ air heaters transfer heat through the walls of a plate or tube.

30. ______________________ air heaters move metal sheets through combustion gases for collecting heat and then rotate to a fresh air stream to deposit heat.

31. A rotary air heater is an example of a ____________________________ air heater.

32. ______________________ superheaters are shielded from the radiant heat of the furnace.

33. ______________________ superheaters are exposed to the radiant heat of the furnace.

34. One adaptation of the separately fired superheater is the ______________________.

35. ___________________________ is the spraying of feedwater into superheated steam to lower its temperature.

36. Extended surface tubes are a type of tube that is found in ______________________.

Process Steam Systems II-Test 2

1. What is the minimum size of the pipes connecting the boiler to the water column?

   A. 3/4 inch
   B. 1.0 inch
   C. 1/2 inch

2. Why are crosses used instead of ells on water column connections?

   A. Cost less
   B. Have more strength
   C. Line may be easily cleaned

3. Can you have valves between boiler and water column?

   A. Yes, if they are locked or sealed open
   B. No, they might be closed accidentally
   C. Only if the boiler is under 100 h.p.

4. At what temperature will the tin in fuse plug melt?

   A. 350 degrees F.
   B. 450 degrees F.
   C. 550 degrees F.

5. In the H.R.T. boiler, the fuse plug is located in the rear head, __________ inches above the top row of tubes.

   A. 2 inches
   B. 1/2 inch
   C. 1 inch

6. A siphon coil (pigtail) employed in steam gauge line protects __________.

   A. Bourdon tube
   B. Piping
   C. Draft gauge

7. What type of shut off would be preferable on a pressure gauge line if a valve is not used?

   A. Non-return
   B. Needle type
   C. Cock with a T or lever type handle

8. Steam gauges shall have a dial graduation of at least __________.

   A. 1 1/2 times the M.A.W.P.
   B. Same pressure as boiler
   C. 2.0 times the M.A.W.P.

9. What is the function of a feed water regulator?

   A. Controls temperature of water
   B. Control solids in water of boiler
   C. Control water level in a boiler

10. When two stop valves are used on steam outlet line, it is good practice to have one valve ____________________.

   A. Slow opening
   B. Automatic non-return
   C. Quick opening

11. Is the valve stem connected to the disc on an automatic non-return valve?

   A. No
   B. Yes
   C. Only when open

12. What must you have between two stop valves on the steam outlet or header line?

   A. Thermocouple
   B. Dial actuated thermometer
   C. Drain

13. On a globe valve used on feed piping, the inlet shall be ____________________.

   A. Immaterial
   B. Above the valve disc
   C. Under the valve disc

14. Which valve offers very little resistance to a flow?

   A. Gate
   B. Globe
   C. Check

15. Which valve is used where a flow in one direction only is desired?

   A. Gate
   B. Globe
   C. Check

16. A boiler with more than 500 square feet of water heating surface must have ____________________.

   A. One safety valve
   B. Two or more safety valves
   C. Three safety valves
   D. Four safety valves

17. If a boiler is fired to full capacity, the header valve being closed, the safety valve or valves should prevent steam pressure from raising more than ____________________.

A. 4% above S.W.P. or valve setting
B. 5% above S.W.P. or valve setting
C. 6% above S.W.P. or valve setting
D. 10% above S.W.P. or valve setting

18. The maximum steaming capacity of a boiler shall be based on the ______________________________________.

A. Capacity of the fuel-burning equipment, air supply, draft, etc.
B. Ability of the fireman
C. Type of boiler under test
D. Temperature of the boiler feed water

19. One or more safety valves on the boiler proper shall be set ______________________.

A. At or below the maximum allowable working pressure
B. Not more than 6% above the maximum allowable working pressure
C. Not more than 10% above the maximum allowable working pressure
D. Not more than 15% above the maximum allowable working pressure

20. If additional valves are used, the highest pressure setting shall not exceed the maximum allowable working pressure by more than ________________________.

A. 3%
B. 4%
C. 5%
D. 6%

21. Safety valves shall be __________________.

A. Positive weight
B. Direct spring loaded type
C. Combination of weight and spring
D. Doesn't make any difference

22. Dead-weight or weighted-lever safety valves may be used ________________________.

A. When pressure is under 100 pounds P.S.I.
B. Never
C. Only by permission of boiler inspector
D. Under 15 pounds P.S.I.

23. When not more than two valves of different sizes are mounted singly the relieving capacity of the smaller valve shall be not less than ________________ of that of the larger valve.

A. 20%
B. 35%
C. 50%
D. 70%

24. The safety valve or valves shall be connected to the boiler independent of any steam connection.

A. If under 100 pounds P.S.I.
B. Always
C. If furnace is stoker fired
D. If requested by inspector

25. No valve of any description shall be placed between the required safety valve or valves and the boiler nor on the discharge pipe between the safety valve and the atmosphere ________________________.

A. If over 15 pounds P.S.I.
B. If over 100 pounds P.S.I.
C. Without written permission from the state boiler inspector
D. At any time

26. If a discharge pipe is used on the safety valve, the cross-section area shall be ______________________.

A. Not less than the full area of the valve outlets
B. Two times the full area of the valve outlets
C. Three times the full area of the valve outlets
D. It doesn't make any difference

27. Safety valves shall operate without chattering and shall be set and adjusted to close after blowing down not more than ________________________________.

A. 4% but not less than 2 pounds P.S.I.
B. 3% but not less than 4 pounds P.S.I.
C. 6% but not less than 4 pounds P.S.I.
D. 10% but not less than 2 pounds P.S.I.

28. The spring in a safety valve in service for pressure up to and including 250 pounds P.S.I. shall not be used for any pressure more than __________________________ below that for which it is designed.

A. 2% above or 2%
B. 6% above or 6%
C. 10% above or 10%
D. 12% above or 12%

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29. For pressure above 250 pounds P.S.I., the spring shall not be used for any pressure more than ________________ below that for which it is designed.

A. 2% above or 2%
B. 5% above or 5%
C. 6% above or 6%
D. 10% above or 10%

30. Every attached superheater shall have one or more safety valves ____________________.

A. Near the outlet
B. Between boiler and superheater
C. Between superheater and turbine or engine
D. If steam is used to operate turbine

31. Safety valves used on superheater discharging superheated steam at a temperature over 450 degrees F. shall have a body bonnet and spindle of ____________________.

A. Brass
B. Cast iron
C. Malleable iron
D. Steel alloy

32. The spring in the above valve must be ____________________.

A. Outside the valve casting
B. Inside the valve casting
C. Doesn't make any difference
D. Spring is not used

33. When a safety valve leaks at a pressure less than that at which it is set to open ______________________.

A. Tighten the tension of the spring until it stops
B. Keep opening and closing valve by lifting lever to see if it stops
C. Have valve repaired or replaced
D. It doesn't matter if safety valve leaks some

34. The only time it is permissible to set the popping point of a safety valve higher than the S.W.P. is when ____________________.

A. The boiler is less than five years old
B. O.K.'d by the state boiler inspector
C. There is more than one valve, one may be 3% above S.W.P.
D. There is more than one valve, one may be 6% above S.W.P.

35. Where boilers are connected into a common steam header and operate under the same pressure ____________________.

A. No valve may be set higher than the S.W.P. on the weakest boiler
B. All valves may be set 20% higher than the lowest S.W.P.
C. Some valves may be set 20% higher than the lowest S.W.P.
D. Set valves according to the S.W.P. of each individual boiler

36. Blow back is the ____________________.

A. Number of minutes the valve operated before closing
B. Volume of steam discharged
C. Difference between the popping and the closing points of the safety valve
D. Pressure when valve closes

37. When two or more safety valves are used on a boiler, they may be mounted ____________________.

A. on a T
B. on a Y
C. Cross

38. Chattering or rumbling of the safety valve may be due to ______________________.

A. Steam too wet
B. Broken spring
C. Dirt or scale on valve seat or disc
D. Valve coming loose from boiler

39. The variation of the reading on the steam gauge and popping point of a safety valve should not be more than ______________________ pounds P.S.I.

A. 2
B. 4
C. 6
D. 5

40. The minimum blow back on a safety valve of 100 pounds is ________ pounds.

A. 6
B. 2
C. 4

41. How often should you pop a safety valve on a high pressure boiler?

A. As often as needed
B. Daily
C. Yearly
D. Monthly

Process Steam Systems II-Test 1 Answers

1. By the sq. ft. of boiler surface, over 500 sq. ft. of surface, two or more safety valves are required.

2. Low and high water alarms, pet-cocks, pressure gauge.

3. Relief valve.

4. Yes, the check valves that are in the valves that turn the sight glass off.

5. 3 inches as a minimum.

6. Yes, it has a drain on it and also a place to hold the sight glass

7. A. Steam Pressure
   B. Stainless Steel
   C. Outside Stem & Yoke
   D. All Iron
   E. Rising Stem
   F. Water Oil & Gas

8. To prevent thermal shock.

9. Stop valve - check valve. Stop valve.

10. A gate valve or slow opening valve.

11. So the operator can see if the valve is open.

12. Plug type because the seat and plug can be refinished.

13. Rid the boiler of mud and impurities, lower water level in the boiler, and drain the boiler down altogether.

14. One which takes five complete turns to open.

15. It operates like a normal check valve and will allow flow only in one direction.

16. It is a plug type valve. Ball valves.

17. True

18. False

19. False

20. True

21. True

22. True

23. False

24. False
25. True
26. False
27. Economizers
28. Integral
29. Recuperative
30. Regenerative
31. Regenerative
32. Convection
33. Radiant
34. Twin furnace
35. Desuperheating
36. Economizers

Process Steam Systems II-Test 2 Answers

1. B
2. C
3. A
4. B
5. A
6. A
7. C
8. A
9. C
10. B
11. A
12. C
13. C
14. A
15. C
16. B
17. C
18. A
19. A
20. A
21. B
22. B
23. C
24. B
25. D
26. A
27. A
28. C
29. B
30. A
31. D
32. A
33. B
34. C
35. A
36. C
37. B
38. C
39. D
40. B
41. A

Test II is from Stationary Steam Engineering Curriculum, Minnesota Curriculum Services Center, 3554 White Bear Avenue, White Bear Lake, Minnesota 55110. This Guide contains numerous tests and supplementary material.

Competency:

1. Describe the types of and purposes for the steam and water devices which are necessary for the boiler's efficient operation.
2. Identify the instruments that are used to control and measure boiler operation.
3. Explain the function of the auxiliary equipment which is part of the steam power plant operation.
4. Demonstrate the ability to install feed water devices.

Instructional Objectives:

1. Explain the operation of feedwater heaters and feedwater pumps.
2. Identify the reasons condensate tanks with pumps are used.
3. Diagram the equipment on a feedwater line.
4. Describe the different types of feedwater regulators.
5. Explain the function of desuperheaters and pressure-reducing stations.
6. Describe the operation of combustion controls.
7. Identify temperature measurement devices used in boiler operation.
8. Identify pressure measurement devices used in boiler operation.
9. Identify flow and level measurement devices used in boiler operation
10. Identify the feedwater controls used in boiler operation.
11. Identify steam temperature control methods used in boiler operation.
12. Describe the function of condensers, feedwater heaters, deaerators, evaporators, and cooling towers for steam power plant operation.
13. Diagram the components of a simple steam plant.
14. Install a feedwater pump.
15. Install a feedwater regulator.

Learning Activities:

1. Read Chapters 4, 8 and 9 in High Pressure Boilers.
2. Read the Boilers - Instruments and Controls Information Sheet.
3. Read the Steam Plant Auxiliaries Information Sheet.
4. Read the Bulletin "Fluid Control Valves" from Watts Regulator Company.
5. Inspect the measuring instruments and controls on display in your classroom.
6. View the videotapes "Heat Exchangers and Operation of Plant Auxiliaries," "Condensate and Feedwater System," and "Instrumentation and Control - 1: Process Measurement" (NUS Training Corporation).
7. Complete Tech Check 4, Tech Check 8, and Tech Check 9.
8. Complete the Instruments and Auxiliaries Worksheet.
9. Complete Assignment Sheet 1, "Diagram a Feedwater Line."
10. Complete Assignment Sheet 2, "Diagram a Steam Plant."

Application Exercises:

1. Install a feedwater regulator.
2. Install a feedwater pump.

Evaluation/Checkout:

1. Submit Tech Check 4 and Tech Check 9.
2. Submit Assignment Sheets 1 and 2.
3. Submit the Instruments and Auxiliaries Worksheet.
4. Submit your checklist of application exercises.
5. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Have available for display several examples of measurement and control instruments used in boiler operation.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Steingress, F. and Frost, H. High Pressure Boilers. Homewood, Illinois: American Technical Publishers, 1986. An instructor's manual is available which contains the answers to the Tech Check exercises and the answers to the tests in Chapter 12. The test pages in the text are perforated and can be removed.
2. A copy of the information sheets, worksheet and answers, assignment sheets, and test and answers is included with this unit.
3. The Bulletin "Fluid Control Valves" (F300) is available from: Watts Regulator, c/o Advance Industrial Marketing, P. O. Box 87, 923 S. Bird Street, Sun Prairie, WI 53590, (608) 837-5005. Contact Rich Davison, Jr.

Audio Visual Materials:

A. The videotapes "Heat Exchangers and Operation of Plant Auxiliaries," "Condensate and Feedwater System," and "Instrumentation and Control - 1: Process Measurement" are available from NUS Training Corporation. The "Heat Exchangers and Operations of Plant Auxiliaries" is part of the Plant Auxiliaries section of the Power Principles series. The Plant Auxiliaries topic introduces the auxiliary equipment associated with the flow of fluids through plant systems. It discusses how fluid flows through piping systems; how fluid flow is affected by valves, traps, and strainers; and how centrifugal pumps and positive displacement pumps operate. It also examines compressors, fans, and heat exchangers.

The "Heat Exchangers and Operation of Plant Auxiliaries" tape covers the following topics:

1. Heat Exchangers and Heat Transfer
2. Shell and Tube Heat Exchangers
3. Feedwater Heaters and Deaerators
4. Condensers and Evaporators
5. Operating Plant Auxiliary Equipment

The "Condensate and Feedwater System" tape is part of the Plant Systems section of the Power Principles series. At the conclusion of the Plant Systems topic, trainees should understand the operation and function of components found in typical plant systems, and know how water and steam flow through these systems. They will be familiar with the symbols used to represent various components on system diagrams and with the operator checks important in maintaining efficient operation of plant systems and components.

The "Condensate and Feedwater System" tape covers the following topics:

1. System Functions and Components
2. Flow Path
3. Pumps
4. Pumps-Operator Checks
5. Closed Feedwater Heaters
6. Open Feedwater Heaters
7. Hotwell Level Control System

The "Instrumentation and Control - 1: Process Measurement" tape is part of the Pulp and Paper Operation series. The tape opens with a discussion of the functions of instrumentation in measuring process variables. This unit identifies commonly measured process variables and teaches techniques for reading instruments that monitor and control these variables. Descriptions of the principles of instrumentation used to measure and indicate pressure, temperature, level, and flow follow.

A workbook is supplied with each unit.

Resources:

1. Books:
    - A. Warring, R. Pumping Manual. Houston, Texas: Gulf Publishing Company, 1984.
    - B. Warring, R. Pumps - Selections, Systems, and Applications. Houston, Texas: Gulf Publishing Company, 1984.
    - C. Pumps. Washington, D.C.: National Association of Plumbing, Heating, Cooling Contractors, 1979.
    - D. A listing of other books is detailed in Process Steam System I.

2. Audio-Visual Material:
   A. "Heat Exchangers 1 & 2," "Principles of Instrumentation," "Drum Level and Combustion Control," "Pressure and Flow Measurement," "Level and Temperature Measurement," and "Instrumentation and Control 2, 3, 4 & 5" are videotapes available from NUS Training Corporation.
   B. "Centrifugal Pumps 1 & 2," "Positive Displacement Pumps 1 & 2," "Pumps and Drives," and "Pumps 1, 2 & 3" are videotapes available from NUS Training Corporation.
   C. "Troubleshooting Centrifugal Pumps," "Troubleshooting Positive Displacement Pumps," "Centrifugal Pumps: Principles and Troubleshooting," and "Centrifugal Pumps: Disassembly, Inspection and Reassembly" are videotapes available from Industrail Training Corporation.
   D. "Centrifugal Pump Maintenance" is a videotape available from Marshall Maintenance Productions.
   E. "Centrifugal Pumps 1 & 2" are videotapes available from Tel-A-Train, Inc.

Boilers - Instrumentals and Controls Information Sheet

The safe and efficient operation of a steam generation plant is dependent upon the proper control of temperature, pressure, levels and flow of air, fuel, water and steam. This can only be accomplished with the help of control equipment.

These variables must be measured and that measurement must be shown in a visible dial or gauge. This unit is designed to acquaint apprentices with the measuring instruments and how the measurements reach the dials and gauges.

The instrumentation and control devices must measure such things as temperature, pressure, fluid flow and fluid levels. Other control devices monitor feedwater, combustion and steam temperature.

Measurement Devices

Temperature Measurement Devices

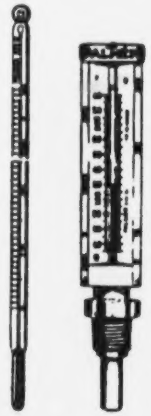
Heat transfer involves changes in temperature. The following items must have temperature control and thus must be measured regularly.

1. Steam
2. Feedwater
3. Oil
4. Cooling water
5. Flue gas

There are many types of instruments for measuring temperature. These include:

1. Glass stem thermometers
2. Remote indicating bulb thermometers
3. Bi-metallic thermometers
4. Thermo-electric pyrometer

The glass stem thermometer operates with a column of mercury or alcohol in a glass tube. Mercury filled thermometers are suitable for high temperatures. Alcohol filled thermometers are best suited to low temperatures.



Glass-stem Thermometers

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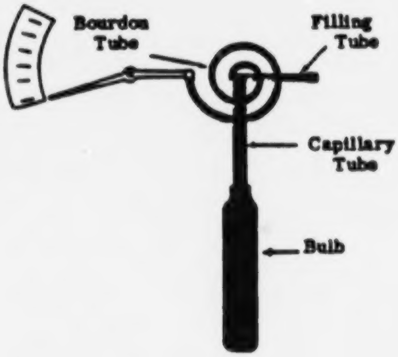
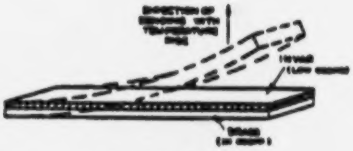
A remote-indicating bulb thermometer is used to record temperatures away from the site of measurement. This thermometer is made of a Bourdon tube, a capillary tube and a bulb. Changes inside the tube cause the Bourdon tube to expand or contract. The Bourdon tube is attached to an indicator arm.



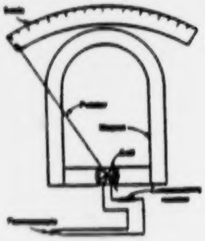
Remote Bulb Thermometer

Bi-metallic thermometers are made of thin metal strips of different metals. The metals expand at different rates because of differences in metallurgical properties of the two metals. As the metals are welded together, expansion causes a bending action which moves the indicator. Brass and an iron nickel alloy are commonly used as metal strips.



Bimetal Strip

A thermo-electric pyrometer is actuated by a thermo-couple which responds to temperature change by increasing or decreasing its voltage output.



Thermoelectric Pyrometer

Pressure Measurement Devices

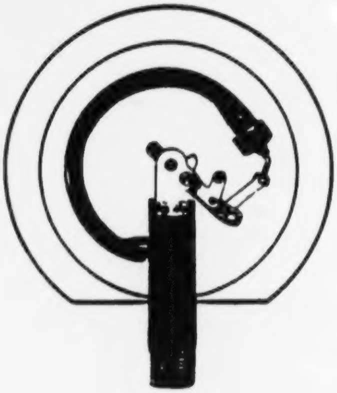
Some of the common pressure measurements are:

1. Steam
2. Feedwater
3. Furnace
4. Condenser
5. Oil

The devices used to measure pressure include:

1. Bourdon tubes
2. Bellows pressure gauge
3. Diaphragm pressure gauge

The Bourdon tube is shaped in the form of a C, spiral or helix. The open end of a Bourdon tube is attached by a linkage mechanism that moves an indicator. Increases in pressure cause the tube to straighten and move the indicator.



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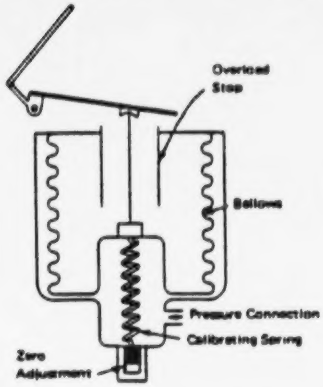
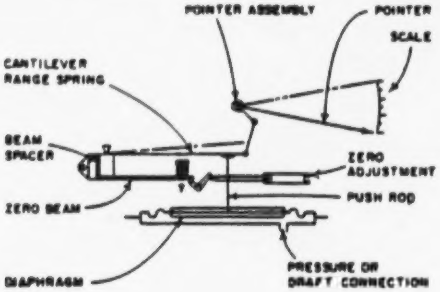
A bellows pressure gauge is a corrugated chamber that expands along its length. Pressure on the bellows causes expansion. This expansion moves a linkage to the indicator which registers change in pressure.

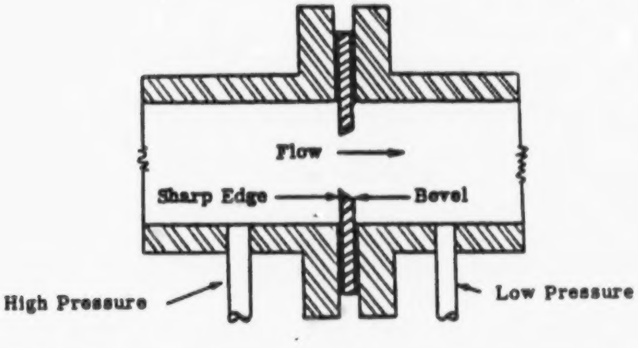

Overload Stop
Bellows
Pressure Connection
Calibrating Spring
Zero Adjustment

The diaphragm pressure gauge utilizes a liquid filled u-tube that is connected to the pressure sources at one end. The other end of the u-tube is connected to the atmosphere. The difference in pressure at the two ends of the u-tube is measured. Pressure on the diaphragm moves one side of the u-tube which, in turn, moves the indicator arm.

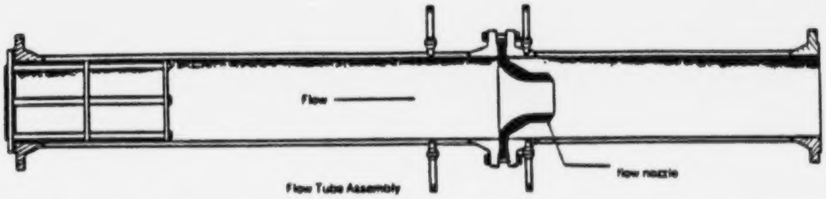

POINTER ASSEMBLY
POINTER
SCALE
CANTILEVER RANGE SPRING
BEAM SPACER
ZERO ADJUSTMENT
PUSH ROD
ZERO BEAM
DIAPHRAGM
PRESSURE OR DRAFT CONNECTION

Flow Measurement Devices

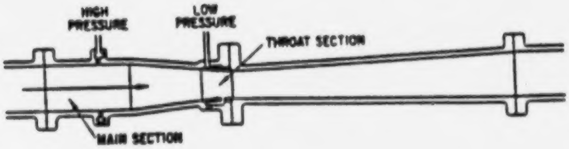
The rate of flow must be measured for steam, feedwater, fuel and air. Flow is measured by measuring pressure drops across a constriction within the pipe. A constriction increases velocity and decreases pressure of the substance flowing through a pipe. In measuring the flow of steam an orifice plate is used as a means to constrict flow.


Flow
Sharp Edge
Bevel
High Pressure
Low Pressure

Liquid flow uses a flow nozzle or venturi tube to constrict the flow for measurement.


Flow
Flow Tube Assembly
flow nozzle

Flow Nozzle


HIGH PRESSURE
LOW PRESSURE
THROAT SECTION
MAIN SECTION

Venturi Tube

The actual measurements are made with pressure measuring devices. The flow is proportional to the square root of the pressure drop at the constriction.

Level Measurement Devices

Devices are needed to measure the levels of liquids such as:

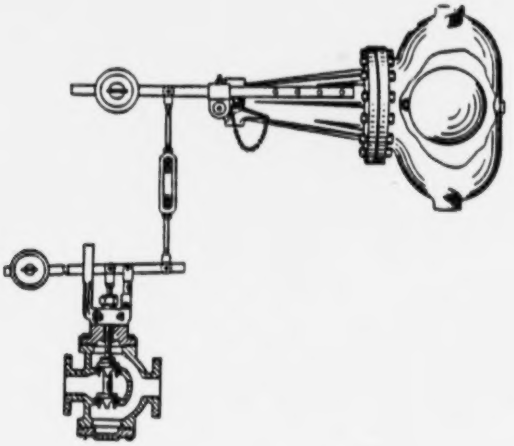
1. Boiler water
2. Storage tanks
3. Fuel tanks
4. Condenser hot well

The devices most commonly used to measure levels include:

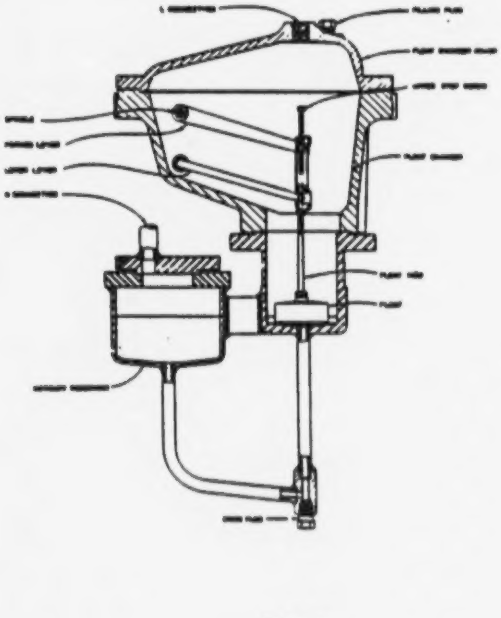
1. Gauge glasses
2. Float weight device
3. Float cage
4. Differential pressure gauge

The gauge glass has been discussed in detail in the previous modules. Float weight devices use floats inside the tank which are attached to a scale device outside. The float moves up and down with the water level and changes the measurements on the scale.

Float cage units are attached to a container on the outside. It is connected to the liquid near the bottom of the tank and to the vapor space above the liquid. As the levels change, the float moves up and down. The level is measured on an indicator scale.



The float manometer is a differential pressure gauge. The manometer is attached to the top of the vessel. A mercury reservoir responds to the rise and fall of liquid in the vessel. The movement of the mercury moves a float which actuates the indicator.



Controllers, Transmitters and Actuators

A control system consists of three main parts:

1. Controller
2. Transmitter
3. Actuator

Controllers

Controllers sense changes in such things as pressure, temperature and levels and send the signal on to an actuator which can change dials and open valves. The controller must have a sensing device and a signalling device. The signal device may be operated by electrical signal or by pneumatics. Some common controllers are:

1. On-off controller are set to measure above or below a set point. A flapper is held against a nozzle for maximum setting and away from the nozzle for minimum settings.

2. Proportional controllers measures how much a measurement is above or below the set points. These controllers have some problems with offset. Offset is the difference between new corrected valves and the set point valves.

3. Proportional plus integral (reset) controller allows offset problems to be avoided by adding an adjustable restriction and positive feedback bellows to the controller. The feedback bellows serves as a reset that brings measurements back to set point.

4. Proportional plus reset plus derivative controller has, in addition to the reset feature, a controller with a rate action or derivative feature. This feature consists of a restriction in the air line to the feedback bellows. A rate action feature causes a quick return to the set point and the final controls move further in the required direction.

Transmitters

A transmitter measures the signal produced by the controller and converts the signal into transmission signals. The transmission signals are sent to the controller and indicators. Some transmitters contain sensing devices rather than the controller. Transmitters operate on pneumatic or electronic signals.

Transmitters may be classified as:

1. Pressure transmitters
2. Flow transmitters
3. Level transmitter
4. Temperature transmitter

The pressure transmitter uses a sensor of the Bourdon, bellows or diaphragm type. The transmitter is arranged in a flapper-nozzle assembly. They operate on pneumatic or electronic signals.

Flow transmitters use the orifice plate to restrict the flow and produce a pressure drop. A bellows type sensor measures the pressure drop.

A level transmitter uses a float device to move the flapper. A feedback bellows is used to keep the signal output proportional.

Temperature transmitters use a Bourdon tube to move the flapper in relation to the nozzle.

Actuators

Actuators receive signals from the controller and change them into mechanical motion. The pneumatic or electronic signals are changed into mechanical energy for opening valves, dampers, etc. Actuators may be classified according to the signals that they receive -- pneumatic or electronic. Another way to classify actuators is by the type of motion they produce -- rotary or linear. A positioner may be used to amplify the control signal at low pressures and using high pressure air to move the actuator.

Control Systems

Feedwater Controls

Feedwater control systems may be classified as:

1. Thermo-hydraulic
2. Thermo-expansion
3. Single element
4. Two element
5. Three element

The thermo-hydraulic system has a feedwater regulating valve which is actuated by a generator. An outer tube of the generator is connected to the feedwater regulating valve at the bottom. At the top, both inner and outer tubes are connected to the steam and water. Heat from steam in the inner tube cause the water in the outer tube to flash into steam. This forces water into the bellows which controls the opening and closing of the feedwater valve.

Thermo-expansion regulators are a tube mounted on a beam and attached to the steam and water space. As water level drops in tube, its temperature is raised by the steam on its outside. The increased heat expands the tube and actuates the feedwater regulating valve.

Single element control has a drum level transmitter signal differences between drum levels and the set point. This system is used where slow changes are made in the feedwater load. Single element control only responds to the drum level variable.

Two element controls use a system that responds to both drum level and steam flow. The drum level measurement balances water input with steam output. Steam flow measurements proportions water according to the steam flow.

Three element controls measure steam flow, feedwater flow and drum level.

Combustion Control Systems

The flow of fuel and air must be regulated to get good combustion. The ratio of fuel to air must be maintained for combustion efficiency. There are three types of combustion controls:

1. On-off controls
2. Positioning controls
3. Metering controls

The on-off control system consists of a bellows operated switch which is activated by boiler pressure. A drop in pressure will start the fans and burner. This system is inefficient because of the variation of boiler pressure between "cut in" and "cut out" points.

Positioning control involves actuators that position the draft dampers and fuel valve according to the boiler load. A positioning control is operated by a master controller that signals the actuators for dampers and fuel valve.

Metering control use a master controller to signal the damper and fuel valve actuators. In this case, the signals are based on measured or metered amounts of fuel and air.

Steam Temperature Control

The temperature of superheated steam must be constant for turbine efficiency. Methods of temperature control are:

1. Combustion gas bypass which routes combustion gases around the superheater to avoid overly high temperatures.

2. Combustion gas recirculation which recirculates combustion gases over the superheater tubes to raise temperatures.

3. Desuperheating by spraying feedwater into the superheated steam to lower temperature.

4. Tilting burners to vary temperature by tilting burners upward or downward.

5. Twin furnaces used on separately fired superheaters that allows temperature control.

6. Attemperation lowers steam temperature by passing it over attemperator tubes and condensing it.

A three element control for steam temperature uses an attemperator with signals from three sources. The signals come from the steam or air flow meter, the thermal element in the attemperator nozzle, and a thermal element in the second stage superheater. The final steam temperature is determined by the thermal element in the second stage superheater.

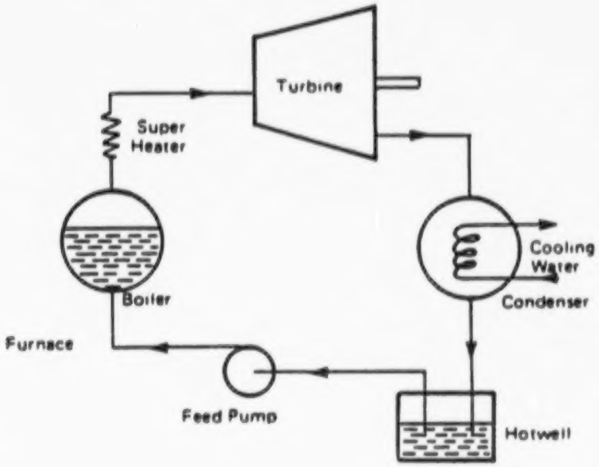
Reference:

1. Boiler Operators Curriculum. Eugene, Oregon: Lane Community College, 1982.

Steam Plant Auxiliaries Information Sheet

The steam turbine is the prime mover of a steam operated power plant. But the turbine must have the help of other equipment to complete its job of converting heat energy into mechanical energy. The equipment that helps convert steam into mechanical energy are called auxiliaries.

A simple steam plant is composed of the following components:



Steam from the boiler passes through a superheater into the turbine. The exhaust steam is transformed into water in the condenser and stored in the hotwell. A feed pump pulls water from the hotwell and supplies it as feedwater back to the boiler.

Condenser

The condenser is a heat exchanger. Its job is to convert exhaust steam to water so that it can be recompressed at boiler pressure. A surface condenser uses river water or a cooling tower to transform the exhaust steam into water. Another method of cooling involves air cooling of finned tubes that carry the steam. A condenser is made of the following parts:

- Shell of welded steel construction with attached hotwell, exhaust neck and support plates.
- Tube Plates made of brass or stainless steel.

- Condenser Tubes of small diameter brass or alloy which are attached or welded to the tube plates.

- Waterbox made of cast iron and bolted to the shell with tube-plate collar bolts.

- Cooling water flow that passes through the waterbox.

The efficiency of a condenser is affected by the arrangement of tube banks. If tubes are properly arranged, the condensate can be reheated and deaerated with steam in the condenser. A condenser that can utilize condenser steam for reheating the condensate is termed a regenerative condenser. A down flow condenser has a steam flow that is vertically downward. Central or radial flow condensers flows steam around the tube banks and radially to the center. Jet condensers use a water spray to cool the steam and both coolant and condensate flow into the hotwell. The ejector condenser is very much like a jet condenser. Exhaust steam enters the cooling water flow and is condensed by mixing.

Air ejectors are needed to remove air from the condenser. Air will build up and blanket the cooling surface. This reduces the efficiency of the condenser. The air ejector expands high pressure steam through a nozzle which converts the heat to kinetic energy. The air ejector ejects trapped air and removes it from the condenser.

A condenser has a number of safety fittings. The atmospheric relief valve releases pressure when pressures within the shell become greater than atmospheric pressure. This prevents rupture of the shell. Large condensers use vacuum pay-off relays and vacuum trip relays to protect against excess pressure in the condenser. A condenser gauge glass shows the level of condensate in the condenser hotwell. Excess water levels in the hotwell can be detected by a high water level alarm. Detection of leaks in the cooling water can be detected by an electrical purity measurement with a dionic tester. A silver nitrate test will detect salt in the cooling water. Manufacturer's instructions for specific condensers should be carefully followed in operating a condenser. Circulating water pumps for moving cooling water are usually a vertical, propeller type, or mixed flow pump. Centrifugal pumps are used with large condensers. Condensate pumps remove the condensate from the hotwell to the aerators. Most condensate pumps are centrifugal type.

Feedwater Heaters

In bleeder turbines, steam is drawn off for the purpose of heating feedwater. As a result of bleeding, less exhaust steam is delivered to the condenser and the efficiency is increased. Feedwater heaters are used to help capture the energy that is normally lost as steam meets the cooling water. There are two classes of feedwater heaters -- low pressure and high pressure types. A feedwater heater has several safety and operational valves:

- Safety valve on the steam side to avoid overpressure problems.

- Relief valve on the waterbox to prevent excess pressure from thermal expansion of water.

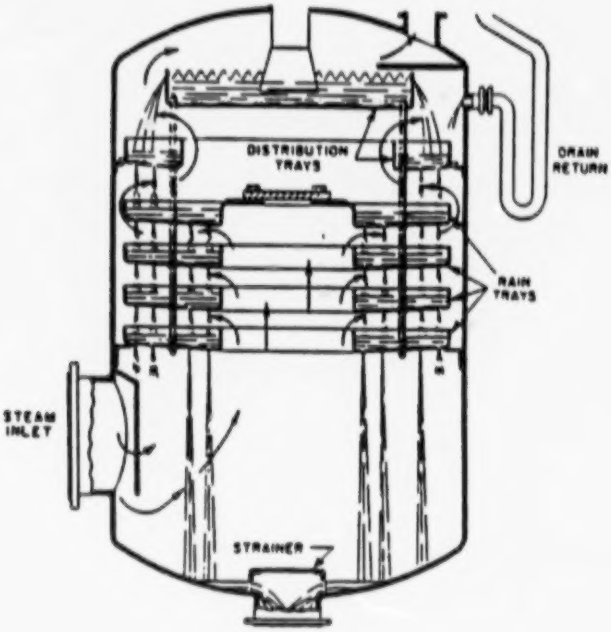
- Non-return valve to prevent steam from returning to the turbine.

- Drain valve for draining off condensate on steam side. Another drain valve on waterbox for draining water.

- Air release valve on steam side to bleed off excess air that blocks entry of steam.

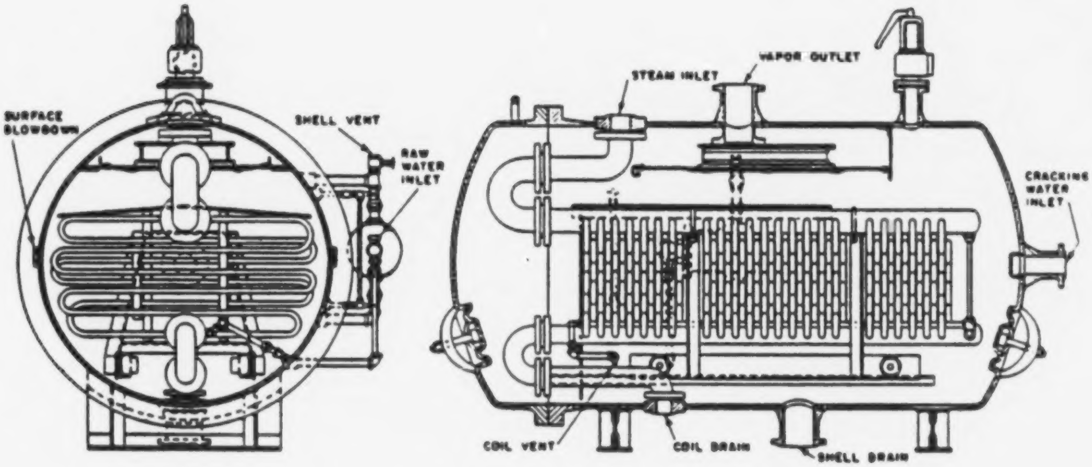
Dearators

A dearator removes the air from the condensate and heats it at the same time. Dearators are often called dearator-heaters. The condensate is heated to the boiling point which releases all gases. After the condensate is heated, it flows down over a series of trays. The condensate flows to the bottom of the tank and the gases move to the top where they are vented off to the condenser. A tray type aerator is shown below.



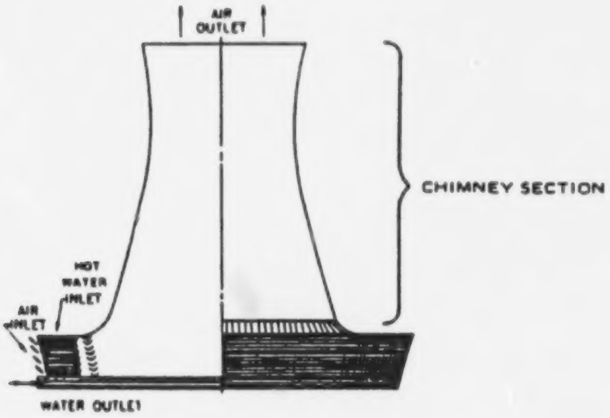
Evaporators

Boilers require a pure feedwater. The feedwater must be free of minerals. The best supply of pure feedwater can be obtained from bleed steam evaporators. Bleed steam is directed at evaporator coils which produce a vapor. The vapor is condensed in a low pressure feedwater heater. The evaporator shell is made of steel and contains a coil and header assembly. The coil is looped inside the shell. Baffles on the coils separate water from vapor. As the water evaporates, the solids (mineral portion) of water are left in the evaporator. The evaporator must be cleaned regularly to remove scale and solids from the evaporation process. Clean surfaces offer better transfer of heat.


SURFACE BLOWDOWN
SHELL VENT
RAW WATER INLET
STEAM INLET
VAPOR OUTLET
CRACKING WATER INLET
COIL VENT
COIL DRAIN
SHELL DRAIN

Cooling Towers

In some settings, cooling water must be used over and over. This requires that the water be cooled after each use. A cooling tower or cooling pond is a common method for re-cooling water. In a cooling tower, the warm water is pumped to the top of the tower and allowed to drop over a series of splash bars. The water returns to the reservoir by gravity flow and is cooled along the way. A hyperbolic draft tower provides a chimney type suction that moves air past the cooling water.



A mechanical draft tower forces air through the tower by a fan. If the fan is located at the base, it is a forced draft type that pushes air toward the top of the tower. An induced draft type has a fan located at the top of the tower and pulls air from the bottom.

Reference:

1. Steam Plant Operators Curriculum. Eugene, Oregon: Lane Community College, 1982.

Assignment Sheet 1

Diagram a Feedwater Line

Draw a boiler main feedwater line and label all components. Briefly describe the function of each of the components.

Assignment Sheet 2

Diagram a Steam Plant

Sketch a simple steam plant complete with all the auxiliary equipment outlined in this module. Briefly describe the function of the equipment.

Instruments and Auxiliaries Worksheet

Indicate what the following devices are used to measure. Show by placing a code letter in the space at the front of the device. Pressure (P), Temperature (T), Flow (F), Level (L).

1. _____ Venturi tube
2. _____ Bourdon tube
3. _____ Gauge glass
4. _____ Glass stem
5. _____ Float cage
6. _____ Orifice plate
7. _____ Remote indicating bulb
8. _____ Bellows gauge
9. _____ Thermo-electric pyrometer
10. _____ Diaphragm gauge

Match the following terms and descriptive phrases.

11. _____ Condenser shell
12. _____ Waterbox
13. _____ Tube plates
14. _____ Feedwater heaters
15. _____ Dearator
16. _____ Air ejector
17. _____ Evaporator
18. _____ Condenser gauge glass
19. _____ Hyperbolic cooling tower
20. _____ Induced draft tower

A. Used with bleeder turbines.

B. Uses chimney type suction for air flow.

C. Removes air and gases from condensate.

D. Has a fan located at bottom.

E. Made of welded steel construction.

F. Removes mineral from feedwater.

G. Made of cast iron.

H. Made of brass or stainless steel.

I. Shows level of condensate in hotwell.

J. Removes air from condenser.

21. Describe the operation of a low water cut-off.

22. How would you check a low water cut-off when the boiler is running?

23. What is a OS&Y valve?

24. Describe a single element water control.

25. Describe a two element water control.

26. Draw a water column on a boiler drum with the following:

A. crosses
B. piping
C. caps & nipples
D. OS&Y valves
E. try cocks
F. blow down valves

27. Why is a large float used in the float and cage water feeder?

28. What is the minimum pipe size for piping a water column to a boiler drum?

29. What is the minimum pipe size for a blow down on the water column and gauge glass?

30. What is the minimum sight glass or gauge glass size on the water column?

Instruments and Auxiliaries Worksheet Answers

1. F
2. P
3. L
4. T
5. L
6. F
7. T
8. P
9. T
10. P
11. E
12. G
13. H
14. A
15. C
16. J
17. F
18. I
19. B
20. D
21. When the water level in the boiler drops below the low water limit or within 3" of the top of the tubes in a HRT boiler, the control will break the power to the main fuel valve and shut down the boiler.
22. By blowing down the control and seeing if the main fuel valve drops out. Looking at the wires and at the mercury tubes to see if they are alright, checking the wire insulation and junction box terminals for bare spots and loose wiring.
23. Outside screw and yoke valve.
24. A control that works off of one source of information. Examples are float valves, thermal valves, and density controls valves.
25. A control that takes two sources of information and reacts accordingly.
26. See text.
27. So that it will have the power to open or close a feedwater valve.
28. 1" pipe
29. 3/4" pipe
30. 1/2" pipe size

Process Steam Systems III Test

Show these devices as controllers, transmitters or actuators by placing (C) for controller, (T) for transmitter or (A) or actuator in the blank space.

1. _____ On-off type
2. _____ Level
3. _____ Proportional plus integral reset
4. _____ Flow
5. _____ Temperature
6. _____ Pressure
7. _____ Rotary
8. _____ Linear
9. _____ Pneumatic
10. _____ Electronic

Fill in the Blanks.

11. A __________________ pump pulls water from the hotwell and supplies it as feedwater to the boiler.

12. A __________________ condenser uses river water or a cooling tower to transform exhaust steam into water.

13. A __________________ condenser utilizes condenser steam for reheating the condensate.

14. __________________ condensers use a water spray to cool the steam.

15. Cooling water leaks can be detected by an _______________ _______________ measurement with a dionic tester.

16. Salt contamination of cooling water can be detected with a _______________ _______________ test.

17. Most condensate pumps are __________________ type pumps.

18. A __________________ removes air from the condensate and heats at the same time.

19. The best supply of pure feedwater can be obtained by using __________________ __________________ evaporators.

20. A mechanical draft cooling tower with a fan located in the base is a ____________________ draft type.

21. Name five things that will cause a low water condition in a boiler.

22. What devices can be connected to the top of a water column?

23. What type of fittings should be used to pipe a water column to a steam drum?

24. Draw a OS&Y valve and list where it can be used on the water column piping. Also list what position the valve should be in.

25. Explain the operation of a feedwater regulator that is a single element type.

26. Why is a two element control used in some boilers? How does the two element control work?

27. Describe the inspection of a low water cut-off that uses a mercury switch.

28. What is the minimum pipe size for a gauge glass blow down?

Process Steam Systems III Test Answers

1. C
2. T
3. C
4. T
5. T
6. T
7. A
8. A
9. A
10. A
11. Feed pump
12. Surface
13. Regenerative
14. Jet
15. Electrical purity
16. Silver nitrate
17. Centrifugal
18. Dearator
19. Bleed steam
20. Forced
21. Piping leaks, boiler leaks, boiler feedpump not working, leaking steam vents, insufficient condensate return.
22. Whistle alarm, top sight glass valve, pressure gauges.
23. Crosses with nipples and pipe caps.
24. Between boiler and the water column. It must be locked in the open position.
25. It is a simple float operated regulator which opens and closes the make up water valve in accordance with the water level in the boiler.
26. As boiler water drops in the drum, steam pressure will increase in the superheaters. This helps control the make up water. The boiler water level depends on expansion and contraction of a rod which opens and closes the valve. Temperature and pressure are used to make up water.
27. The switch should be checked to make sure that the glass has not lost its vacuum. The mercury should be checked for discoloration and the wires checked for cracks or breakage.
28. 3/4 inch

Competency:

1. Explain how steam heating systems work.
2. Describe the various types of steam heating systems.
3. Describe the function of the fittings and accessories used on a steam heating system.
4. Repair and maintain steam heating systems.

Instructional Objectives:

1. Differentiate between high pressure and low pressure steam heating systems.
2. Explain the use of steam tables and define the measurements that compose the tables.
3. Classify and describe steam heating systems according to the pressure or vacuum conditions.
4. Classify and describe steam heating systems according to the method of condensation flow to the boiler.
5. Classify and describe steam heating systems according to the piping arrangement.
6. Classify and describe steam heating systems according to the type of piping circuit.
7. Classify and describe steam heating systems according to the location of condensation return.
8. Identify the control components that are used to regulate steam boilers and provide safe and efficient operation.
9. Explain the main considerations in the design and installation of steam and condensate piping connections.
10. Troubleshoot a steam heating system, describing in detail, symptoms, their probable causes and corresponding remedies.
11. Describe five types of expansion joints.
12. Explain the purpose of pressure reducing valves.
13. Describe the operation of pressure reducing valves.
14. Draw a single line sketch of a pressure reducing valve installation.
15. Draw a simple sketch of a two-pipe, gravity, steam heating system.
16. Draw a simple sketch of a two-pipe, high pressure, steam heating system.
17. Draw a simple sketch of a Hartford return connection.
18. Install a pressure reducing valve.
19. Install a boiler water feeder on a low water cut-off.
20. Repair/replace a gate valve on a steam heating system.
21. Construct a Hartford return connection for a steam heating system.
22. Repair/maintain an expansion joint.

Learning Activities:

1. Read Chapter 8, "Steam Heating Systems," and pp. 469-519 in Chapter 15, "Boiler and Boiler Fittings," in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Heating Boilers" - Lecture 11, and "Heating Accessories and Systems" - Lecture 12 in the Boiler Fireman's Course and read "Steam Heating" - Lecture 9 in Building Systems Technician - Course 2.
2. Read the "Service Guide" (Bulletin SL-SG) from McDonnell and Miller on boiler feeder cut-offs.
3. Read "Basic Controls for Low Pressure Steam Boilers" (Bulletin SL-BCS) from McDonnell and Miller.
4. Read "Thermostatic Temperature Regulators and Tempering Devices" (Bulletin TR-987) from Hoffman Fluid Technology Division/ITT Corporation.
5. Read pp. 1-7 in "Steam Conservation Guidelines for Condensate Drainage" (M101) from Armstrong Machine Works.
6. Read "Pressure Reducing Valves" (AY-110-A) from Armstrong Machine Works.
7. Read "Pressure Reducing Valves" (Bulletin PRV-385) from Hoffman Fluid Technology Division/ITT Corporation.
8. Read "Steam Pressure Regulators" (F-127-4) from Watts Regulator Company.
9. Read the Expansion Joints Information Sheet.
10. View the videotapes "Let's Talk PRV's" and "Guidelines for Steam System Efficiency" (Armstrong Machine Works).
11. Complete Assignment Sheet 1, "Diagram a Pressure Reducing Valve Installation."
12. Complete Assignment Sheet 2, "Diagram a Two-Pipe, Gravity, Steam Heating System."
13. Complete Assignment Sheet 3, "Diagram a Hartford Return Connection."
14. Complete the Steam Heating Systems Worksheet.

Application Exercises:

1. Install a pressure reducing valve.
2. Install a boiler water feeder or a low water cut-off device.
3. Repair/replace a gate valve on a steam heating system.
4. Construct a Hartford return connection for a steam heating system.
5. Repair/maintain an expansion joint.
6. Troubleshoot a steam heating system, describing in detail, symptoms, their probable causes and corresponding remedies.

Evaluation Checkout:

1. Submit Assignment Sheets 1, 2, and 3.
2. Submit the Steam Heating Systems Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Brumbaugh, J. Heating, Ventilating, and Air Conditioning Library - Volume I. New York: Macmillan Publishing Company, 1986.
2. Boiler Fireman's Course. Calgary, Alberta: Southern Alberta Institute of Technology, 1987.
3. Building Systems Technician - Course 2. Calgary, Alberta: Southern Alberta Institute of Technology, 1986.
4. "Service Guide" (Bulletin SL-SG) and "Basic Controls for Low Pressure Steam Boilers" (Bulletin SL-BCS) are available from McDonnell and Miller Fluid Technology, ITT Corporation, Marketing Services Department, 3500 N. Spaulding Avenue, Chicago, IL 60618, (312) 267-1600.
5. "Thermostatic Temperature Regulators and Tempering Valves" (Bulletin TR 987) and "Pressure Reducing Valves" (Bulletin PRV 385) are available from Hoffman Fluid Technology Division/ITT Corporation, Marketing Services Department, 1700 West 10th Street, Indianapolis IN 46222, (317) 632-7546.
6. "Pressure Reducing Valves" (AY-110-A) and "Steam Conservation Guidelines for Condensate Drainage" (M101) are available from Pamela G. Blasius, Marketing Services Department, Armstrong Machine Works, 816 Maple Street, Three Rivers, MI 49093, (616) 273-1415.
7. "Steam Pressure Regulators" (F-127-4) is available from Rich Davison, Jr., Watts Regulator Company, c/o Advance Industrial Marketing, P. O. Box 87, 923 S. Bird Street, Sun Prairie, WI 53590, (608) 837-5005. A condensed catalog of the equipment Watts Regulator Company manufactures is available. Order CBV-845 and C-85B.
8. A copy of the information sheet, worksheet and answers, assignment sheets, and test and answers is included with this unit.

Audio Visual Materials:

1. The videotapes "Let's Talk PRV's" and "Guidelines for Steam System Efficiency" are available from Pamela G. Blasius, Marketing Services Department, Armstrong Machine Works, 816 Maple Street, Three Rivers MI 49093, (616) 273-1415. "Let's Talk PRV's" looks at the reasons for, configurations of, and means of evaluating pressure reducing valves. "Guidelines for Steam System Efficiency" covers basic considerations in the design, piping and trapping of steam systems.

Resources:

1. Books:
   - A. A listing of books is detailed in Process Steam System I.

2. Pamphlets:
   - A. "The Armstrong Humidification Handbook" (HB-500-C) is available from Armstrong Machine Works. The address is given above.
   - B. "Steam Pressure Regulator Selector" (Slide Chart) and "Pressure Reducing Valves" (F-PV10) are available from Watts Regulator Company. The address is given above.
   - C. Piping Technology and Products, Inc. catalog contains information on expansion joints, hangers, and pipe shoes. Their address is: P. O. Box 34506, Houston, TX 77234-4506.
   - D. "Steam Needs Analysis Program" is available from Spirax Sarco, Inc., P. O. Box 119, Allentown, PA 18105, (215) 797-5830.
   - E. "Regulator and Relief Valve Reference Guide" (Form 7475) is available from Fisher Controls, Inc., P. O. Box 190, Marshalltown, IA, 50158.
   - F. "Spirax Sarco Condensed Catalog" is available from Spirax Sarco, Inc., P. O. Box 119, Allentown, PA 18105, (215) 797-5830. This catalog contains information on their temperature and pressure controls, steam traps, steam meters, air removal, condensate recovery pumps, humidifiers, and pipeline auxiliaries.

3. Audio-Visual Materials:
   - A. "It's the Humidity" is a videotape available from Armstrong Machine Works.

4. Seminar:
   - A. Rich Davison, Jr. from Advance Industrial Marketing will present information on the products of Watts Regulator Company. The address is given above.

Expansion Joints Information Sheet

Expansion joints and loops in long heating lines are ways pipe expansion is handled. The pipeline is anchored at certain points where excessive movement due to expansion occurs, and bends or expansion joints are placed in the line between the anchored points. There are five main types: (1) expansion loops, (2) slip joints, (3) swing joint, (4) bellows joint, and (5) ball joints.

Expansion Loops - Expansion loops absorb pipe expansion by using U or Z loops in the pipe line. If the bends are made to a large enough radius, the expansion loop will take care of considerable expansion in a pipeline. The drawback to this approach is the amount of space the bend takes up.

Slip Joint - This type of joint consists of a smooth sleeve which slides in or out through a packing box as the pipeline expands or contracts. There is an outer casing or body which is anchored, a sliding tube or sleeve which fits into the body, and packing which is used to prevent leakage between the inner and outer sections. The packing is held in place by a gland and studs. In a low-pressure expansion joint, tie rods are used so the two halves of the joint do not pull apart, and a soft packing is used. In a high-pressure expansion joint, internal traverse stops are used instead of the tie rods and a metallic packing rather than a soft packing, is used. Flanges are provided for connecting the joint into the pipeline. Proper alignment is essential for this type of joint to function properly.

Bellows Expansion Joints - Expansion in this type of joint is taken care of by the flexing of a metal bellows. The joint may be a corrugated bellows type or a multidisc bellows type. The corrugated bellows type consists of a corrugated, thin-walled copper tube which is clamped between the flanges and has rings to help keep the corrugations in the joint under high pressures. The multidisc bellows type has an internal sleeve which acts as a stop to limit the flexing of the discs. With the bellows welded to the two halves of the joint, no packing box is necessary and the joint is steamtight. In this type of joint, misalignment should be reduced to a minimum for proper installation.

Swing Joint - This type of joint is most often used to allow for expansion and it is best adapted to screwed joints.

Ball Joints - Ball joints have four basic parts: (1) the body casing to hold the gaskets and the ball, (2) the ball, a hollow fitting, which is shaped like a ball at one end and is inside the casing, and it is threaded, flanged, or adapted for welding to the pipe at the other end, (3) two gaskets which hold the ball and provide the seal, and (4) a retaining nut or flange to hold the ball and gaskets in the casing. The end of one of the two pipes being coupled is connected to the joint casing, and the end of the other is connected to the ball.

Maintenance - In terms of maintenance, the expansion joints must be properly aligned, if there is packing, adequately packed, and it must be within the proper limit of travel.

Selection - The number and type of expansion joints installed in a line depends on the amount and direction of expansion and the amount of expansion permitted by each joint. The linear expansion of piping can be determined by the following formula: Expansion in inches per hundred feet of pipe = Coefficient of Expansion x (Final Temperature - Starting Temperature). For example, the expansion of a 300' steel steam line with a final temperature of 320 degrees and a starting temperature of 60 degrees Fahrenheit is:

$$E = .00804 \times 260 = 2.09 \text{ in. per 100 hundred feet}$$
$$3 \times 2.09 = 6.27 \text{ in. per 300 hundred feet}$$

Coefficients of expansion can be determined by using pipe expansion tables.

Piping Anchors and Guides

For an expansion joint to operate properly, the pipe line must be securely anchored. In addition, the pipeline must have enough guides or supports to prevent buckling or bowing of the pipe and to allow movement of the pipe as it expands and contracts. The guides should be installed near an expansion joint to hold the pipe in the proper position for the best operation of the joint.

Anchors are used to divide the system into sections, so that each expansion joint absorbs only the expansion of its own section. When several expansion joints are used, the pipe may be anchored halfway between the joints or else at the joints themselves if they are fitted with anchor bases.

References:

1. Elonka, S. and Higgins, A. Standard Boiler Room Questions and Answers. New York: McGraw-Hill, 1982.
2. Langley, B. Boiler Operations. New York: Harcourt, Brace, and Jovanovich, 1988.
3. Building Systems Technician. Calgary, Alberta: Southern Alberta Institute of Technology, 1986.

Assignment Sheet 1

Diagram a Pressure Reducing Valve Installation

Draw a simple single line sketch of a pressure reducing valve installation and explain the purposes of the various valves and fittings required.

Assignment Sheet 2

Diagram a Two-Pipe, Gravity, Steam Heating System

Draw a two-pipe, gravity, steam heating system showing air vents, two radiators, pitch of pipe, return line, and necessary valves.

Assignment Sheet 3

Diagram a Hartford Return Connection

Draw a simple sketch of a Hartford return connection.

Steam Heating Systems Worksheet

1. How would you define steam?

2. A. What is absolute pressure?

   B. What is gauge pressure?

3. What is saturation temperature?

4. What is:
   A. Latent Heat?

   B. Sensible Heat?

5. What is the latent heat for the following pressures?

A. 1.3 psig = ________ BTU's/lb
B. 10.3 psig = ________ " "
C. 2.0 psia = ________ " "
D. 15.0 psia = ________ " "
E. 15.3 psig = ________ " "
F. 30.0 psia = ________ " "

6. What is the sensible heat for the following pressures?

A. 1.3 psig = ________ BTU's/lb
B. 15 psig = ________ " "
C. 30 psia = ________ " "

7. Define the term "Saturated Steam".

8. Define the total heat of steam.

9. List the total heat for the following pressures:

A. 1.3 psig = ________ BTU's/lb
B. 10.3 psig = ________ " "
C. 15.0 psia = ________ " "
D. 30.0 psia = ________ " "

10. If a steam coil has a 96,000 BTU's per hour capacity, at 5 psig steam pressure how many pounds of condensate will be formed?

11. Same as question 10 but the steam pressure is 15 psig.

12. The volume of steam at 7 psig is ________. If a leak would occur in a steam line, would it leak more steam or hot water if the opening was the same size in both systems? Explain your answer:

13. Is there a pressure drop in a steam system? Explain:

14. What is a Hartford Loop and why is it important?

15. Explain what pitch is required for the supply main in a one pipe gravity system.

16. Name two types of radiator valves.

17. List where air vents should be placed in a one pipe gravity system.

18. Why is it important to quickly vent the piping and units in a one and two pipe gravity system?

19. The vacuum in the return piping of a vacuum heating system is usually around ________________________.

20. How is condensate returned to the boiler in a two pipe mechanical system?

21. What is a "balanced system"?

22. What is a downfeed system?

23. Why are vacuum return steam heating systems so costly?

24. List three advantages of using high pressure steam for a heating system.

A.

B.

C.

25. Which valve body takes less power to operate? Why?

26. What are some of the considerations in sizing a reducing valve?

27. Explain how a weight and lever valve works.

28. What are some of the piping considerations of a steam pressure reducing station? List three or more.

29. What are some of the advantages and disadvantages of the spring or ball type of return valve?

30. Name and describe five expansion joints.

Steam Heating System Worksheet Answers

1. Steam is the gaseous state of water. It is an invisible gas caused by the induction of heat into water until the water reaches saturation temperature and changes into saturated steam.

2. A. All pressure above a perfect vacuum.

   B. All pressure above atmospheric pressure.

3. Boiling point for water at a set temperature and pressure point. Where water temperature is as high as it can go and still be water at that pressure.

4. A. Change of state heat.

   B. Change in temperature heat.

5. A. 967.6
   B. 952.1
   C. 1022.2
   D. 969.7
   E. 945.3
   F. 945.3

6. A. 184.42
   B. 218.8
   C. 218.8

7. Steam that is at its boiling temperature at that given pressure. Steam that contains droplets of the water from which it was formed.

8. All of the heat in the steam, sensible as well as latent heat.

9. A. 1152.0
   B. 1160.6
   C. 1150.8
   D. 1164.1

10. Latent heat of 5 psig steam = 960 BTU's/lb.

    100 lbs. of condensate
    960 BTU/lb. | 96,000 BTU's

11. Latent heat of 15 psig steam = 945 BTU's/lb.

    101.6 lbs. of condensate
    945 BTU | 96,000 BTU's

12. 18.4 cu. ft./lb.

13. Not if pipe size is adequate. The steam will fill all of the voids in the steam piping and equipment. Steam traps drain away the spent steam or condensate as it accumulates in the low points in the system.

14. The Hartford Loop is designed to protect boilers against loss of water under a condition that would let water flow out of the boiler because of a leak in the return piping.

    The Hartford Loop is a water seal on the return piping on a boiler that is piped to the balance pipe at a point just below the water line of the boiler. The tie-in should be at a point on the balance line that will leave 3" to 4" of water in the boiler above the tubes or crown sheet before the steam breaks the water seal.

15. 1/2" in. 20'

16. Packless type and open packing type
    Angle and/or straight through

17. At the end of the supply mains and at the start of the return piping at the units.

18. So the steam will fill the pipe and units faster and the space being heated will be heated evenly.

19. 6" to 8" hg.

20. Condensate pump or a feed water pump.

21. A system that needs no make-up water. When the steam is out in the system the condensate will return before the boiler reaches the low water limit.

22. Where the branch pipe comes off the steam supply main and downfeeds the units. The branch pipe may come off the side or bottom of the supply main but always downfeeds with a riser with a trap at the end.

23. Because of the cost of the vacuum pump. It costs more than 5 times as much as a condensate pump and receiver.

24. A. Heating units are smaller.

    B. Smaller pipe sizes can be used to carry the same amount of BTUs.

    C. Large amount of BTUs to heating units.

25. The double seated valve because as the inlet pressure is pushing down on the bottom plug it is also pushing up on the top plug and as a result they balance each other. A smaller spring or diaphragm can be used on this type of valve.

26. A. The type of application. Is it needed for a "dead-end" operation?

    B. Pressure range that must be controlled, 3 to 15 psig or 200 to 5 psig?

    C. The amount of volume needed. Large and changing amount or a steady small volume load?

27. The controlled pressure is adjusted by moving the weight as needed on the lever. The relatively constant pressure exerted by the weight and lever coupled with the sensitivity of the pilot valve provides close control.

28. A. Dry saturated steam at all times to supply the reducing valve.

    B. A globe valve in a bypass around the automatic reducing valve.

    C. High and low pressure gauges.

    D. Safety valve on the low pressure side.

    E. Strainer in front of the reducing valve.

29. This valve is self contained and needs no control pipe. It is smaller so it takes up less room. The disadvantage is that it should not be used on large and fluctuating loads.

30. See the information sheet.

Process Steam Systems IV Test

1. Define:

   A. Latent heat of steam

   B. Sensible heat

   C. Saturation temperature

   D. Gauge pressure

E. Absolute pressure

2. What is the latent heat for the following:

A. 15.3 psig = ________ BTUs/lb.
B. 30.3 psig = ________ BTUs/lb.
C. 7.3 psig = ________ BTUs/lb.

3. Between 0 and 100 psig, which pressure steam contains the most latent heat?

4. How much more latent heat does it contain than 50 psig steam?

5. Boiler feedwater is heated to 201.3 degrees F. The water at 201.3 degrees F. contains how many BTUs of sensible heat.

6. How many lbs. of condensate will 196,000 BTUs of steam at 15 psig make?

7. Draw a one pipe steam heating system showing air vents, two radiators, pitch of pipe, and a dry return to the boiler.

   OR

   Write one paragraph covering the same thing.

8. Draw a "Hartford Loop" OR write a paragraph on how to install one on a steam boiler.

9. Draw a two pipe gravity steam heating system and show where it was an improvement over the one pipe system.

OR

Write two paragraphs covering the same thing as the drawing.

10. Where should a condensate pump and receiver be located?

11. Describe an unbalanced steam heating system.

12. Are there two different pressures in a two pipe mechanical steam system? Explain.

13. Are there two different pressures in a two pipe gravity steam heating system? Explain.

14. What steam system has the most advantages and the least disadvantages?

15. Where should packless radiator valves be used instead of packed type?

16. Describe a high pressure steam heating system.

17. List some advantages and some disadvantages of high pressure steam heating systems.

18. How can a vacuum return steam heating system be used off of a high pressure boiler?

19. Define the following:

    A. Type of application for a reducing valve.

B. Single seated valve.

C. Double seated valve.

20. Describe how a spring steam reducing valve with a control pipe operates.

21. In one paragraph or with a drawing show how to pipe a pressure reducing station with a bypass and pilot operated reducing valve. If it is a drawing, label the different parts of the station.

22. Why do most pressure reducing valves hang down instead of the powerhead being up in the steam line?

23. How is the bypass valve piped and why?

24. What is dry saturated steam and why is it important in a steam pressure reducing station?

25. Describe a high pressure and low pressure slip expansion joint.

26. What maintenance is required on expansion joints?

27. How do you select the proper type and number of expansion joints?

Process Steam Systems IV Test Answers

1. A. Change of state heat.
   B. Change in temperature heat.
   C. Water at temperature before boiling and changing to steam.
   D. All pressure above atmospheric pressure.
   E. Pressure above a perfect vacuum.

2. A. 945.3
   B. 928.6
   C. 956.3

3. 0 gauge = 970.4

4. 58.8 BTU

5. 169.96

6. 207.34

7. See text.

8. See text.

9. See text.

10. As close to the boiler as possible.

11. The process uses up the condensate and water must be added to keep the boiler water level normal.

12. Yes. Due to the use of traps we have at least a 50% differential.

13. Yes. Due to the length of the lines and friction of the fittings we have a pressure differential. This is overcome by using 18" of head to get the water back to the boiler.

14. Two pipe mechanical system.

15. In vacuum systems or where valve stem packing leaks cannot be tolerated.

16. High pressure uses 16-150 lbs. steam, is a two pipe system, and uses reducing valves or stations.

17. Advantages: smaller pipe sizing, large amount of BTUs to heating units, heating units are smaller.

    Disadvantages: final air temperature is higher, therefore care of heater placement is necessary, risk of injury, higher cost of equipment.

18. By installing a pressure reducing station between the high pressure process and the low pressure heating system.

19. A. When high pressured steam is used to supply a low pressure steam heating system.

    B. For complete shutoff, more expensive, and less flow then a two-seated.

    C. Two seats with the pressure on top of one and under the other. It is not used for complete shutoff.

20. Spring pressure is used to hold the valve open. Steam pressure works on the diaphragm to close the valve. As the pressure downstream builds up, it closes the valve. The line must be full of water to stop the steam from reaching the diaphragm.

21. See text and readings.

22. The pilot line then fills with water and keeps the live steam from the diaphragm.

23. It is piped with two pressure gauges, one on each side of the globe valve. This way the pressure reducing valve can be removed and the pressure can still be controlled.

24. Steam which corresponds to its pressure and temperature. It contains no water droplets. This results in less wear on the valve.

25. See the information sheet.

26. See the information sheet.

27. See the information sheet.

Competency:

1. Define steam trapping terminology.
2. Identify applications for steam traps including location, installation and sizing.
3. Demonstrate the ability to repair and install steam traps.

Instructional Objectives:

1. Define flash steam.
2. Define condensate.
3. Describe how the heat of steam is utilized.
4. Explain why it is necessary to remove condensate, air, and CO from a steam system.
5. Explain the purpose and function of steam traps.
6. List the advantages and disadvantages of float and thermostatic traps.
7. List the advantages and disadvantages of thermostatic bellows type traps.
8. List the advantages and disadvantages of thermostatic bimetal traps.
9. List the advantages and disadvantages of disc traps.
10. List the advantages and disadvantages of orifice traps.
11. List the advantages and disadvantages of bucket traps.
12. Draw and explain the proper piping of steam trap installation that will avoid flow and expansion problems.
13. Calculate trap sizing and safety load factors.
14. Explain the purpose of pipe line strainers.
15. Describe the function of rotary joints and syphons.
16. Repair and install a mechanical trap.
17. Repair and install a thermostatic trap.
18. Repair and install a thermodynamic trap.

Learning Activities:

1. Read "Engineering Data Manual-Steam Traps" (Bulletin STD-787) from Hoffman Fluid Handling Division/ITT Corporation.
2. Read "Steam Conservation Guidelines for Condensate Drainage" (M101) from Armstrong Machine Works.
3. Read "Inverted Bucket Traps" (Bulletin IBT-287) from Hoffman Fluid Handling Division/ITT Corporation.
4. Read the Information Sheet "Trapping Superheated Steam Mains" from Armstrong Machine Works.
5. Read the article "Strainers Must Be Correct Type, Size to Properly Protect Fluid Handling Equipment" from Pulp and Paper Buyers Guide, 1983.
6. Read the article "Principles of Steam Trap Operation...how four basic types maintain steam system efficiency" from Plant Engineering, 1981.
7. Read the Information Sheet "Flash Steam" (Bulletin No. 201) from Armstrong Machine Works.

8. View the videotapes, "The Armstrong Differential Condensate Controller," "Guidelines for Steam Trap Troubleshooting and Testing," "Guidelines for Steam Trap Repair" (Armstrong Machine Works) and "Rotary Joints - Installation and Maintenance" (Marshall Maintenance Productions).
9. Complete Assignment 1, "Diagram a Trap Installation for a Rotary Dryer."
10. Complete Assignment 2, "Diagram a Trap Installation for a Flash Tank."
11. Complete Assignment 3, "Diagram a Trap Installation for a Heat Exchanger."
12. Complete Assignment 4, "Diagram a Trap Installation for a Jacketed Kettle."
13. Complete Assignment 5, "Diagram a Trap Installation for a Process Air Heater."
14. Complete Assignment 6, "Diagram a Trap Installation for a Trap Draining to Gravity Return Line."
15. Complete the Steam Trap Worksheet.

Application Exercises:
1. Repair and install a mechanical trap.
2. Repair and install a thermostatic trap.
3. Repair and install a thermodynamic trap.
4. Calculate a trap sizing problem.

Evaluation/Checkout:
1. Submit Assignment Sheets 1, 2, 3, 4, 5, and 6.
2. Submit the Steam Trap Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Material:
1. "Engineering Data Manual - Steam Traps" (Bulletin STD-787) and "Inverted Bucket Trap" (Bulletin IBT-387) are available from Hoffman Fluid Handling Division/ITT Corporation, Attn: Marketing Services Department, 1700 West 10th Street, Indianapolis, IN 46222
2. "Steam Conservation Guidelines for Condensate Drainage" (M101), "Trapping Superheated Steam Mains," "Strainers Must Be the Correct Type, Size to Properly Protect Fluid Handling Equipment," "Principles of Steam Trap Operation...how four basic types maintain steam system efficiency," and "Flash Steam" (Bulletin No. 201) are available from Pamela G. Blasius, Marketing Services Department, Armstrong Machine Works, 816 Maple Street, Three Rivers, MI 49093 (616) 273-1415.
3. A copy of the worksheet and answers, assignment sheets, and test and answers is included with this unit.

Audio-Visual Material:

1. The videotapes "The Armstrong Differential Condensate Controller," "Guidelines for Steam Trap Troubleshooting and Testing" and "Guidelines for Steam Trap Repair" are available from Armstrong Machine Works at the address given above. The first tape discusses the standard steam trap, drainage method, and the blow-through method of condensate removal in the paper, textile, and boxboard industries. The second tape gives a step-by-step approach to steam trap testing and problem solving. The third tape covers repair procedures that should be performed after the trouble has been isolated in a steam trap.
2. The videotape "Rotary Joints - Installation and Maintenance" is available from Marshall Maintenance Productions. The tape shows the function of the joint and how it is repaired and installed.

Resources:

1. Books:
   A. A listing of books is detailed in Process Steam System I.

2. Pamphlets:
   A. "Water Hammer Problem" (Bulletin No. 206-A), "Troubles in Return Lines" (Bulletin No. 203), "Vacuum Isn't Vacuum to an Inverted Bucket Steam Trap" (Bulletin No. 202), "Preventing Short Circuiting of Steam" (Bulletin No. 200), "Armstrong Float Type Liquid Drainers" (Bulletin No. 401-G), "Drainage of Water and Oil from Compressed Air" (Bulletin 251-B), "Trapping Superheated Steam - Application Guidelines," "Armstrong Compound Traps for Very Heavy Loads" (Bulletin No. 216-A), "Steam Coils Recommended Practice for Piping Layout and Trap Selection," "Steam Trap Fact Sheets" and "Steam Trap Testing Flow Chart" are available from Armstrong Machine Works at the address given above.
   B. "Steam Trap Rx - Preventative Maintenance." Techdata Sheet April 1985 85-15, Department of the Navy, Naval Civil Engineering Laboratory, Port Hueneme, CA 93043.
   C. "Traps, Regulators, Strainers, and Vent Valves" (Bulletin CL-987) is available from Hoffman Fluid Technology Corporation at the address given above.
   D. "Liqui-Mover Condensate Handling Systems" (Bulletin LM 1006) and "Johnson Rotary Pressure Joints" (Bulletin CB) are available from the Johnson Corporation, 805 Wood Street, Three Rivers, MI 49093 (616) 278-1715.

3. Audio-Visual Materials:
   A. "Piping Auxiliaries 1 & 2" are videotapes available from NUS Training Corporation.
   B. "Let's Talk Steam Traps/Update," "A Matter of Principle," "Anatomy of the Inverted Bucket," "Solving the Water Hammer Puzzle" and "Thermostatic Steam Traps" are available from Armstrong Machine Works at the address given above.
   C. "Vacuum Pumps, Air Ejectors, Strainers, and Traps" is a videotape available from Industrial Training Corporation.

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Assignment Sheet 1

Diagram a Trap Installation for a Rotating Dryer

Sketch a rotating dryer installation complete with necessary joints, fittings, syphon, and steam trap. Assume a dryer 6 ft. in diameter, 12 ft. in width and a condensing rate of 8 lbs./sq. ft.-hr. Specify safety factor and a type of steam trap. Explain why that trap was selected. Use p. 34 in "Steam Conservation Guidelines for Condensate Drainage" as a guide.

Assignment Sheet 2

Diagram a Trap Installation for a Flash Tank

Sketch a flash tank installation complete with all necessary fittings and connections including a check valve, a by-pass, air vent, and steam trap. Specify a safety factor and a type of steam trap. Explain why that trap was selected.

Assignment Sheet 3

Diagram a Trap Installation for a Heat Exchanger

Sketch a heat exchanger installation complete with all necessary fittings and connections including valves, pressure gauges, strainers, and steam trap. Assume a water flow rate of 60 GPM with an entering temperature of 45 degrees F. and a leaving temperature of 150 degrees F. Steam pressure is 20 psig. Specify a safety factor and a type of steam trap. Explain why that trap was selected. Use p. 26 in "Steam Conservation Guidelines for Condensate Drainage" and pp. 17-18 in "Engineering Data Manual - Steam Traps" as a guide.

Assignment Sheet 4

Diagram a Trap Installation for a Jacketed Kettle

Sketch a jacketed kettle installation complete with all necessary fittings and connections including strainer, check valve, syphon, and steam trap. Assume a 40 inch gravity drained kettle at 25 psig steam. Specify a safety factor and a type of steam trap. Explain why that type of steam trap was selected. Use pp. 30-31 in "Steam Conservation Guidelines for Condensate Drainage" and p. 22 in "Engineering Data Manual - Steam Traps" as a guide.

Assignment Sheet 5

Diagram a Trap Installation for a Process Air Heater

Sketch a process air heater installation complete with all necessary fittings and connections including control valve, strainer, and steam trap. Assume a tunnel dryer coil handling 2,500 CFM of air and requiring a 125 degree F. temperature rise, the steam pressure is 50 psig. Specify a safety factor and a type of steam trap. Explain why that trap was selected. Use. p. 24 in "Steam Conservation Guidelines for Condensate Drainage" as a guide.

Assignment Sheet 6

Diagram a Trap Installation for a Trap Draining to Gravity Return Line

Sketch a trap installation for a gravity return line complete with all necessary fittings and connections including a dirt pocket, strainer, valves, shutoff, and steam trap. Specify a steam trap and explain why that type was selected.

Steam Trap Worksheet

1. Define saturated steam.

2. Define sensible heat.

3. Define latent heat.

4. Define total heat.

5. Explain the method for sizing steam traps.

6. List three advantages, three disadvantages, and three applications of float and thermostatic steam traps.

7. List three advantages, three disadvantages, and three applications of bucket steam traps.

8. List three advantages, three disadvantages, and three applications of thermostatic bellows steam traps.

9. List three advantages, three disadvantages, and three applications of thermostatic bimetal steam traps.

10. List three advantages, three disadvantages, and three applications of disc steam traps.

11. Define what flash steam is and explain what use it has.

12. Explain why condensate drainage is necessary.

13. What may the problem be if the trap blows live steam?

14. What may the problem be if no condensate is coming to the trap?

15. What may the problem be if the trap fails to discharge condensate?

Steam Trap Worksheet Answers

1.-4. p. 9, "Engineering Data Manual - Steam Traps."

5. p. 8, "Engineering Data Manual - Steam Traps."
pp. 14-15, "Steam Conservation Guidelines for Condensate Drainage."

6.-10. pp. 3-6, "Engineering Data Manual - Steam Traps."

11. p. 3, "Steam Conservation Guidelines for Condensate Drainage."

12. pp. 5-6, "Steam Conservation Guidelines for Condensate Drainage."

13.-15. p. 40, "Steam Conservation Guidelines for Condensate Drainage."

Process Steam Systems V Test

1. Describe with the aid of sketches, the operation of a:

    a. mechanical trap
    b. thermostatic trap
    c. thermodynamic trap

2. Explain water hammer in steam and water lines by stating its cause, undesirable effects, and how it can be avoided.

3. What are return and nonreturn traps?

Fill in the blanks.

4. Steam separators are used to separate ____________________ from steam.

5. Steam traps are used to discharge ____________________ and ____________________ from the steam lines.

6. The operation of the ____________________ trap depends on the difference in temperature of steam and condensate.

7. A ____________________ should be installed ahead of a trap to prevent entry of foreign matter.

8. Pressure measured in pounds per square inch above a vacuum is called ____________________.

   a. atmospheric pressure
   b. absolute pressure
   c. gauge pressure
   d. psig

9. Saturated steam ____________________.

   a. is "wet" steam
   b. contains more heat than dry steam
   c. is the "white" steam coming out of a kettle's spout
   d. is "dry" steam

10. The amount of heat in one pound of water before the water is turned to steam is called the ____________________.

   a. latent heat
   b. sensible heat
   c. inherent heat
   d. potential heat

11. When hot condensate under pressure is released to a lower pressure, the result is called ____________________.

   a. superheated steam
   b. heat of vaporization
   c. saturated steam
   d. flash steam

12. Condensate must be purged from steam lines ________________.

a. for efficiency
b. to prevent water hammer
c. to release air and other gases
d. all of the above

13. Mechanical steam traps ___________________.

a. respond to differences in temperature between steam and condensate
b. respond to differences in density between steam and condensate
c. respond to differences in pressure between steam and condensate
d. none of the above

14. Thermostatic steam traps __________________.

a. respond to differences in temperature between steam and condensate
b. respond to differences in density between steam and condensate
c. respond to differences in pressure between steam and condensate
d. none of the above

15. Which of the following statements is true regarding the bellows trap?

a. The bellows trap does not handle air as efficiently as the inverted bucket trap.
b. On startup, the bellows element is fully closed.
c. The bellows element is partially filled with distilled water in most makes.
d. The bellows element opens at a temperature above that of the saturated steam.

16. Steam tracer lines are often drained with __________________.

a. mechanical traps
b. thermostatic traps
c. thermodynamic traps

17. Thermodynamic steam traps ___________________.

a. can be installed only in the horizontal position
b. rely mainly on gravity to operate
c. work very well at higher steam pressures
d. use a ball-float mechanism

18. Which type of trap throttles the main valve to discharge condensate at the same rate it flows into the trap?

    a. inverted bucket
    b. float and thermostatic
    c. bellows
    d. controlled disc

19. Which type of trap can fail to open if it loses its prime?

    a. disc trap
    b. F & T trap
    c. inverted bucket trap
    d. none of the above

20. Which type of trap is particularly sensitive to conditions of high back pressure?

    a. inverted bucket trap
    b. F & T trap
    c. bellows trap
    d. disc trap

Process Steam Systems V Test Answers

1. pp. 8-13, "Steam Conservation Guidelines for Condensate Drainage." pp. 3-6, "Engineering Data Manual - Steam Traps."

2. p. 2, "Engineering Data Manual - Steam Traps."

3. Return traps are designed to return water of condensation to the boiler, against the boiler pressure. The term nonreturn applies to traps of any type that have no live steam connection direct from the boiler and that simply discharge the condensate to waste or to a hot-water receiver against little or no back pressure.

4. water

5. water and air

6. thermostatic

7. strainer

8. b.

9. d.

10. b.

11. d.

12 d.

13. b.

14. a.

15. c.

16. c.

17. c.

18. b.

19. c.

20. d.

Competency:

1. Describe the basic thermodynamics of refrigeration.
2. Define and identify components of the basic mechanical refrigeration cycle.
3. Identify basic components of an air conditioning system.

Instructional Objectives:

1. Define heat, temperature, and BTU.
2. Explain the difference between heat and temperature.
3. Define sensible, specific, and latent heat.
4. Describe states of conditioned air.
5. Distinguish between compression refrigeration components and absorption refrigeration components.
6. Identify types of compressors, evaporators, and condensers.
7. Describe types of metering devices commonly in use.
8. Label the state the refrigerant is in at various points in the refrigeration system.
9. Illustrate a basic refrigeration system.

Learning Activities:

1. Read "The Refrigeration Cycle" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
2. Read "Refrigeration System Components" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
3. Read "Refrigeration Compressors" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
4. Discuss in class sessions the Information Sheet from Section A - Unit I "History and Development" from Air Conditioning and Refrigeration Fundamentals.
5. Discuss in class sessions the Information Sheet from Section F - Unit I "Basic Mechanical Refrigeration" from Air Conditioning and Refrigeration Fundamentals.
6. View the videotape "Refrigeration Systems 1&2" (NUS Training Corporation) or "Introduction to Air Conditioning and Refrigeration" (Industrial Training Corporation).
7. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.
8. Complete Assignment Sheet 1, "Draw a Basic Refrigeration System" in Section F - Unit I from Air Conditioning and Refrigeration Fundamentals.

Evaluation/Checkout:

1. Submit Assignment Sheet 1.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
A few of the companies that manufacture Air Conditioning and Refrigeration Trainers are listed below.

Lab-Volt Systems
5785 Pembroke Drive
Madison, WI 53711
Contact Mark Hillerns (District Sales Supervisor)
(608) 273-1152

The Lab-Volt Refrigeration, Air Conditioning, and Heating Training System introduces the fundamental principles of refrigeration, air conditioning, and heating. The program covers modern applications of refrigeration, air conditioning, and heating technology, and develops the skills needed to assemble, maintain, and repair these systems.

The Lab-Volt Refrigeration, Air Conditioning, and Heating Training System uses commercial and industrial components, so that students get first-hand experience on equipment they are likely to encounter on the job. Major components of the System include a demonstrator for the presentation of fundamental principles, student trainers in advanced applications of refrigeration, heat pumps, and air handling systems that enable students to explore system design and operating concepts, and skills trainers that foster student competence in installation, maintenance, and troubleshooting techniques.

Lab-Volt courseware correlates to the System to maximize educational efficiency. Courseware for the systems-level trainers provides a comprehensive set of exercises, featuring clear illustrations and accompanying unit tests. The skills-trainers courseware is provided in individual exercise booklets consisting of job sheets for students to complete.

A full set of support equipment is also available to complete the refrigeration and air conditioning laboratory. Available equipment includes a refrigeration charging station, test equipment, storage cabinets, heavy duty work benches and consumable supplies packages.

Thermal Engineering Company
c/o Brodhead-Garrett
223 South Illinois Avenue
Mansfield, OH 44905
(419) 589-8222

Thermal Engineering has a number of trainers available including an Introductory Refrigeration and Air Conditioning Trainer. This completely self-contained and operating system utilizes an extremely simple flow pattern to make the refrigeration cycle easy to envision by the student. No overlapping piping or criss-crossing of circuits, this system is truly a cycle, even in the difficult reverse cycle mode. Model REF-01 is versatile and adaptable to show the features of many different single evaporator systems. Includes properly placed valves, pressure gauges, and a location to electronic thermometer probes which gives troubleshooting an organized approach. A student lab manual, instructor's guide, and an overhead transparency set are available.

Hampden Engineering Corporation
P. O. Box 563
East Longmeadow, MA 01028-0563
Contact Sheldon Shattuck
(413) 525-3981

Hampden Engineering has a wide variety of trainers available from desktop demonstrators to an industrial refrigeration demonstrator. Their air conditioning demonstrator has been designed to teach the principles of thermo-dynamics as related to the field of air conditioning and refrigeration. Areas covered include airflow, inlet heating and humidification, air cooling, and air reheating. They also have available an individually paced instruction program for their Refrigeration Cycle Trainer.

Learning Materials:

1. "The Refrigeration Cycle," "Refrigeration System Components," and "Refrigeration Compressors" booklets are part of the Air Conditioning Clinic available from the Trane Company, Educational Department, 3600 Pammel Creek Road, LaCrosse, WI 54601-7599.
2. The quizzes are in the back of the Air Conditioning Clinic booklets from the Trane Company.
3. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (800401), a student manual (800402), and a transparency set (800403) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988. The instructor's guide includes performance objectives, suggested activities, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives information sheets, transparency sets, assignment sheets, job sheets, and tests.

Audio-Visual Materials:

1. The videotapes "Refrigeration Systems - 1" and "Refrigeration Systems - 2" are available from NUS Training Corporation.

Refrigeration Systems - 1 introduces the refrigeration process and provides functional descriptions of typical refrigeration systems and components, such as evaporators, condensers, compressors, and receivers. Cooling systems, such as brine systems, are also covered. The concluding segments examine factors that affect refrigeration system operation and typical operator duties.

Refrigeration Systems - 2 focuses on the functions and operation of heating, ventilating, and air conditioning (HVAC) systems. The unit first introduces the overall air conditioning process and then describes typical dust and humidity control devices. It details the operation of equipment typically found in HVAC systems and concludes with a discussion of general HVAC operator duties.

A workbook is supplied with each unit.

2. The videotape, "Introduction to Air Conditioning and Refrigeration" is available from Industrial Training Corporation. The videotape covers heat transfer, phase changes, compression, condensation and expansion, and refrigerant tables. A workbook, instructor's guide, and overhead transparencies are included.

Resources:

1. Books:
    - A. The Trane Company publishes numerous books and pamphlets including the Trane Air Conditioning Manual and the Trane Reciprocating Refrigeration Manual. For a complete list of their material write: The Trane Company, Educational Department, 3600 Pammel Creek Road, LaCrosse, WI 54601-7599.
    - B. The Air Conditioning Contractors of America has numerous books and pamphlets available. A catalog is available from: ACCA, 1513 16th Street, N.W., Washington, D.C. 20036, (202) 483-9370.
    - C. The National Association of Plumbing - Heating - Cooling Contractors has Heating, Ventilating, and Air Conditioning Apprentice training materials available. A publication list is available from: NAPHCC, P. O. Box 6808, Falls Church, VA 22046-1148, (703) 237-8100.
    - D. Stumper, E. and Koral, R., Handbook of Air Conditioning, Heating, and Ventilating. New York: Industrial Press, Inc. 1979.
    - E. Stoecker, W. F., Industrial Refrigeration. Troy, Michigan: Business News Publishing Company, 1981.
    - F. King, T., Basic Refrigeration. Troy, Michigan: Business News Publishing Company, 1979.
    - G. Smith, R., Electricity for Refrigeration, Heating, and Air Conditioning. Albany, New York: Delmar Publishers, 1987.

H. Olivio, C. and Marsh, R., Principles of Refrigeration. Albany New York: Delmar Publishers, 1979.
I. Langley, B., Control Systems for Air Conditioning and Refrigeration. Englewood Cliffs, NJ: Prentice-Hall, 1985.
J. Chatenever, R., Air Conditioning and Refrigeration for the Professional. New York: Wiley, 1988.
K. Althouse, A., Modern Refrigeration and Air Conditioning. South Holland, Illinois: Goodheart-Willcox, 1988.
L. Whitman, W., Refrigeration and Air Conditioning Technology. Albany, New York: Delmar Publishers, 1987.
M. Lang, P., Principles of Air Conditioning. Albany, New York: Delmar Publishers, 1987.
N. Hansen, E., Hydronic System Design and Operation: A Guide to Heating and Cooling With Water. New York: McGraw Hill, 1985.
O. McQuiston, F. and Parker, J., Heating, Ventilating, and Air Conditioning: Analysis and Design. New York: Wiley, 1982.
P. Clifford, G., Heating, Ventilating and Air Conditioning. Reston, Virginia: Reston Publishing Company, 1984.
Q. Haines, R., Control Systems for Heating, Ventilating, and Air Conditioning. New York: Delmar, 1978.
R. Schneider, R., HVAC Control Systems. New York: Wiley, 1988.
S. Copeland Corporation produces a set of Refrigeration Manuals. Contact: Copeland Corporation, 1675 W. Campbell Road, Sidney, OH 43565-0669, (513) 498-3011.
T. Armstrong International, Inc. publishes the Armstrong Guide to Refrigerated Purging. (Bulletin No. 702-C). They also publish a chart on Basic Data on Commonly-Used Refrigerants. Contact: Armstrong International, Inc., Marketing Services, 900 Maple Street, Three Rivers, MI 49093, (616) 273-1415.
U. Mueller Brass Company publishes a concise and well written booklet on Refrigeration and Air Conditioning: Principles and Products (Catalog No. R-2043-86). Contact: Mueller Brass Company, 1925 Lapeer Avenue, Port Huron, MI 48060, (313) 987-4000.
V. Elonka, S. and Minich, Q., Standard Refrigeration and Air Conditioning Questions and Answers. New York: McGraw Hill, 1983.

2. Audio-Visual Materials:
   A. "Air Conditioning Clinic Slides" are available from the Trane Company.
   B. "Principles of Mechanical Refrigeration" booklet and slides are available from Carrier Air Conditioning Training Center, Carrier Parkway, P. O. Box 4808, Syracuse, NY 13221.
   C. "Basic Mechanical Refrigeration Cycle" booklet and slides and "Theory of Refrigeration Slides" are available from BDP Company, Division of Carrier Corporation, Training and Dealer Development, 7310 W. Morris Street, Indianapolis, IN 46231.

Competency:
1. Identify safe practices associated with refrigeration and air conditioning systems.
2. Identify special tools used on air conditioning and refrigeration equipment.

Instructional Objectives:
1. Match terms related to refrigeration and air conditioning safety with their definitions.
2. Complete a list of electrical safety rules.
3. Identify true statements concerning refrigerant related safety rules.
4. List the four highly flammable gases used in the working on air conditioning and refrigeration systems.
5. Complete a list of safety rules for using the air-acetylene torch.
6. Identify statements concerning safety rules for charging or discharging fluorinated hydrocarbon refrigerants.
7. Complete statements concerning safety rules for pressurizing a refrigeration system.
8. Complete statements concerning safety rules for handling refrigerant cylinders.
9. Identify special tools used in air conditioning and refrigeration and their uses.
10. Identify components of the refrigeration gauge set.
11. Match components of the refrigeration gauge set with their uses.

Learning Activities:
1. Discuss in class sessions the Information Sheet from Section B - Unit II "Specific Safety" from Air Conditioning and Refrigeration Fundamentals.
2. Discuss in class sessions the Information Sheet from Section C - Unit II "Special Tools" from Air Conditioning and Refrigeration Fundamentals.
3. Examine the special tools used on air conditioning and refrigeration equipment on display in your classroom.

Evaluation/Checkout:
1. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
Examples of special tools used in the air conditioning and refrigeration trade for classroom display. Examples of the tools that could be displayed are listed on the Information Sheet from Section C - Unit III "Special Tools" in Air Conditioning and Refrigeration Fundamentals.

Learning Materials:

1. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (800401), a student manual (800402), and a transparency set are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988. The instructor's guide includes performance objectives, selected activities, an information sheet, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets, and tests.

Resources:

1. A listing of books and audio-visual materials is detailed in Refrigeration and Air Conditioning I.
2. In the instructor's guide for Air Conditioning and Refrigeration Fundamentals, suggested supplemental materials are listed for each unit.
3. The videotape "Copper Tubing Tools" explains the proper use of tools used to prepare copper tubing for plumbing, heating, and cooling applications. It is available from the National Association of Plumbing, Heating, and Cooling Contractors, P. O. Box 6808, Falls Church, VA 22046.

Competency:

1. Explain the purpose of common refrigeration system accessories.
2. Demonstrate the ability to install common refrigeration accessories.
3. Describe the purpose of a refrigerant in a refrigeration system.
4. Explain the relationship between temperature and pressure in a refrigeration system.
5. Demonstrate use of the vacuum steam table.
6. Demonstrate the ability to evacuate a refrigeration system.

Instructional Objectives:

1. Identify refrigerant system accessories.
2. Select purposes of refrigerant system accessories.
3. Distinguish between factors in selecting a liquid line filter drier and a suction line filter drier.
4. Distinguish between types of service valves.
5. Demonstrate the ability to install a filter drier with flare fittings.
6. Demonstrate the ability to install a filter drier with sweat fittings.
7. Install a liquid indicator with flare fittings.
8. Attach a gauge manifold set using a stem type service valve.
9. Install a line tap access valve.
10. Install an access core type service valve.
11. Match terms related to refrigerants with correct definitions.
12. Match types of refrigerants with their correct applications.
13. List three methods of leak detection.
14. Identify safety precautions for refrigerant handling.
15. Describe the procedure for obtaining refrigeration system pressures.
16. Demonstrate the ability to pressure check an air conditioning system.
17. Demonstrate the ability to fill a charging cylinder.
18. Compute temperature-pressure problems.
19. Identify reasons for evacuating a refrigeration system.
20. Select the effects of air and moisture in a refrigeration system.
21. Outline the effects of ambient temperature on proper evacuation.
22. Distinguish between low and high vacuum pumps.
23. Distinguish between types of vacuum indicators.
24. Demonstrate the ability to use the vacuum table.
25. Demonstrate the ability to evacuate a refrigeration system.

Learning Activities:

1. Read "Refrigeration Accessories and Controls" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
2. Read "The Refrigeration Cycle", pp. 7-16, from the Trane Air Conditioning Clinic.

3. Discuss in class sessions the Information Sheets from Section F - Units II, III, and IV, "Refrigerant System Accessories," "Refrigerants," and "Evacuation" from Air Conditioning and Refrigeration Fundamentals.
4. View the videotapes "Vapor Compression Cycle Designs and Refrigerants" and "Pump Down, Evacuation, and Charging" (Industrial Training Corporation).
5. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.
6. Attend a lecture/discussion by an industry representative.
7. Complete Assignment Sheet 1, "List Cylinder Color Codes" and Assignment Sheet 2, "Compute Temperature - Pressure Problems" in Section F - Unit III from Air Conditioning and Refrigeration Fundamentals.
8. Complete Assignment Sheet 1, "Use the Vacuum Table" in Section F - Unit IV from Air Conditioning and Refrigeration Fundamentals.

Application Exercises:
1. Install a filter-drier with flare fittings.
2. Install a filter-drier with sweat fittings.
3. Install a liquid indicator with flare fittings.
4. Attach a gauge manifold set using a stem type service value.
5. Install a line tap access valve.
6. Install an access core type service valve.
7. Pressure check an air conditioning system.
8. Fill a charging cylinder.
9. Evacuate a refrigeration system.

Evaluation/Checkout:
1. Submit Assignment Sheets.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. A few of the companies that manufacture Air Conditioning and Refrigeration Trainers are listed in Refrigeration and Air Conditioning I.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises for this unit are in the Air Conditioning and Refrigeration Fundamentals manual. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. "Refrigeration Accessories and Controls" and "The Refrigeration Cycle" booklets are part of the Air Conditioning Clinic available from the Trane Company, Educational Department, 3600 Pammel Creek Road, LaCrosse, WI 54601-7599.

2. The quiz is in the back of the Air Conditioning Clinic booklet from the Trane Company.
3. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium 1984. An instructor's guide (800401), a student manual (800402), and a transparency set (800403) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988.
4. The tests, information sheets, and assignment sheets are in the student manual and instructor's guide for Air Conditioning and Refrigeration Fundamentals. The instructor's guide also contains the test answers.
5. Contact a marketing representative or a service technician from an air conditioning/refrigeration manufacturer to present material to the class on industrial refrigeration/air conditioning.

Audio-Visual Material:

1. The videotape, "Vapor Compression Cycle Designs and Refrigerants," and "Pump Down, Evacuation, and Charging," are available from Industrial Training Corporation. The first videotape covers evaporator operation, reciprocating compressor operation, centrifugal compressor operation, condenser operation, and metering devices. The second videotape covers system pump down, system evacuation, high-side charging, low-side charging, and determining proper charge.

Resources:

1. A listing of books and audio-visual material is detailed in Refrigeration and Air Conditioning I.
2. In the instructor's guide for Air Conditioning and Refrigeration Fundamentals, suggested supplemental materials are listed for each unit.
3. Henry Valve Company will provide catalogs, bulletins, and diagrams at minimum charge. Contact Paul Schwarz, Marketing Manager, Henry Valve Company, Inc., 3215 North Avenue, Melrose Park, IL 60160, (312) 334-1100. The available material includes:
   - Oil Control System - Application and Installation
   - Instruction Manual - Charging and Testing Manifold
   - Oil Separators
   - Safety Release Devices for Refrigerant Pressure Vessels
   - The Henry Valve UK-90 Acid Test Kit
   - Preventive Maintenance - Components and Procedures for the Removal of Contaminants From Air Conditioning and Refrigeration Systems.
   - Refrigeration System Diagrams.
   - Valves and Accessories for Refrigeration and Air Conditioning Applications.

Competency:

1. Distinguish between different types of tubing and fittings used in air conditioning and refrigeration installation/maintenance.
2. Identify the proper size and type of tubing and fittings needed for particular air conditioning and refrigeration jobs.
3. Demonstrate the ability to flare, bend, and swage tubing.
4. Identify different piping materials and pipe fittings used in air conditioning and refrigeration installation/maintenance.

Instructional Objectives:

1. Match terms related to tubing with their definitions.
2. Distinguish between nominal size copper tubing applications and ACR copper tubing applications.
3. List applications of aluminum and steel tubing.
4. Identify tube and flexible refrigerant hose fittings.
5. Match terms related to tubing operations with their correct definitions.
6. Identify types of flaring blocks.
7. Demonstrate the ability to make a single flare with a compression type flaring block.
8. Demonstrate the ability to make a single flare with a generating type flaring block.
9. Demonstrate the ability to make a double flare.
10. Demonstrate the ability to make a swage joint.
11. Demonstrate the ability to make a 90 degree bend.
12. Demonstrate the ability to make a 180 degree bend.
13. Demonstrate the ability to make a 45 degree bend.
14. List four types of pipe used in air conditioning and refrigeration.
15. Match types of pipe with their applications in air conditioning and refrigeration.
16. Distinguish between different piping material and pipe fittings used in air conditioning and refrigeration.
17. Complete a list of the advantages and disadvantages of plastic pipe.
18. Arrange in the order the steps in cutting and threading iron pipe.
19. Arrange in order the steps necessary for installing P.V.C. pipe.
20. Determine the lengths of P.V.C. and fittings necessary to construct a condensate line.

Learning Activities:

1. Read "Refrigeration System Piping" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
2. Discuss in class sessions the Information Sheets from Section D - Units I, II, and III, "Tubing," "Tubing Operations," and "Pipe" from Air Conditioning and Refrigeration Fundamentals.
3. Examine the actual fittings, tubing, and pipe used on air conditioning and refrigeration jobs on display in your classroom.

4. Observe as your instructor demonstrates the procedure for cutting and threading pipe, cutting and gluing P.V.C., and the procedure for making a flexible plastic pipe connection.
5. Complete Assignment Sheet 1, "Read Fitting Sizes," and Assignment Sheet 3, "Determine Lengths of P.V.C. and Fittings Necessary to Construct a Condensate Line" in Section D - Unit III from Air Conditioning and Refrigeration Fundamentals.

Application Exercises:
1. Make a single flare with a compression type flaring block.
2. Make a single flare with a generating type flaring block.
3. Make a double flare.
4. Make a swage joint.
5. Make a 90 degree bend.
6. Make a 180 degree bend.
7. Make a 45 degree offset.

Evaluation/Checkout:
1. Submit Assignment Sheets 1 and 3.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:
1. Examples of fittings, tubing, and pipe used on air conditioning and refrigeration jobs for classroom display.
2. Equipment necessary to demonstrate the procedure for cutting and threading pipe, cutting and gluing P.V.C., and the procedure for making a flexible plastic pipe connection.
3. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises for this unit are in the Air Conditioning and Refrigeration Fundamentals manual. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:
1. "Refrigeration System Piping" booklet is part of the Air Conditioning Clinic available from the Trane Company, Educational Department, 3600 Pammel Creek Road, LaCrosse, WI 54601-7599.
2. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, 1984. An instructor's guide (800401), a student manual (800402), and a transparency set (800403) are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988.

3. The quiz is in the back of the Air Conditioning Clinic booklet from the Trane Company.
4. The tests, information sheets, and assignment sheets are in the student manual and instructor's guide for Air Conditioning and Refrigeration Fundamentals. The instructor's guide also contains the test answers.

Resources:

1. Books
    - A. Good Piping Practice. Troy, Michigan: Business News Publishing Company, 1979.
2. A listing of other books and audio-visual materials is detailed in Refrigeration and Air Conditioning I.
3. In the instructor's guide for Air Conditioning and Refrigeration Fundamentals suggested supplemental materials are listed for each unit.

Competency:

1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a swage joint.
3. Demonstrate the ability to silver braze swage joints and silver braze a copper to a steel joint.

Instructional Objectives:

1. Match terms related to soldering and welding equipment with their definitions.
2. Identify safety rules for using soldering and welding equipment.
3. Complete a list of statements concerning lighting, adjusting, and extinguishing the air-acetylene torch.
4. Arrange in order the steps for setting up the oxyacetylene torch.
5. Arrange in order the steps for lighting, adjusting, and extinguishing the oxyacetylene torch.
6. Demonstrate the ability to light and adjust the air-acetylene torch.
7. Demonstrate the ability to light and adjust the halide torch leak detector using propane.
8. Demonstrate the ability to light and adjust the halide torch leak detector using air-acetylene.
9. Demonstrate the ability to light and adjust the oxyacetylene torch.
10. Match terms related to soft soldering with their definitions.
11. Arrange in order the steps in making a solder joint.
12. Distinguish between types of flux for soft solder.
13. List four conditions for creating capillary actions of solders.
14. Demonstrate the ability to clean, flux, and solder a swage joint.
15. Demonstrate the ability to solder an inverted swage joint.
16. Demonstrate the ability to solder a horizontal swage joint.
17. Match terms related to silver brazing with their definitions.
18. Select true statements concerning guidelines for using silver solder flux.
19. Match different temperature ranges with their correct flux characteristics.
20. Arrange in order the steps in using the air-acetylene high temperature wraparound tip for silver brazing.
21. Demonstrate the ability to silver braze an upright swage joint.
22. Demonstrate the ability to silver braze an inverted swage joint.
23. Demonstrate the ability to silver braze a horizontal swage joint.
24. Demonstrate the ability to silver braze a copper to a steel joint.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section E - Units I, II, and III, "Soldering and Welding Equipment," "Soft Soldering," and "Silver Brazing" from Air Conditioning and Refrigeration Fundamentals.
2. Observe as your instructor demonstrates the proper use of soldering and welding equipment and demonstrates soft soldering and silver brazing on swage joints.

Application Exercises:

1. Light and adjust the air-acetylene torch.
2. Light and adjust the halide torch leak detector using propane.
3. Light and adjust the halide torch leak detector using air-acetylene.
4. Clean, flux, and solder a swage joint.
5. Solder an inverted swage joint.
6. Solder a horizontal swage joint.
7. Soft solder with the oxyacetylene torch.
8. Silver braze an upright swage joint.
9. Silver braze an inverted swage joint.
10. Silver braze a horizontal swage joint.
11. Silver braze a copper to a steel joint.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Soldering and welding equipment and equipment necessary to demonstrate soft soldering and silver brazing.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises for this unit are in the Air Conditioning and Refrigeration Fundamentals manual. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. Wantiez, G., Air Conditioning and Refrigeration Fundamentals. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium 1984. An instructor's guide (800401), a student manual (800402), and a transparency set are available. Contact: Mid-America Vocational Curriculum Consortium, 1500 West Seventh Avenue, Stillwater, OK 74074-4364, (800) 654-3988. The instructor's guide includes performance objectives, selected activities, an information sheet, assignment sheets, job sheets, transparency masters, tests, and answers to the tests. The student manual includes the performance objectives, information sheets, transparency sets, assignment sheets, job sheets and tests.

Resources:

1. Books:
   A. Lieberman, E., Modern Soldering and Brazing Techniques. Troy, Michigan: Business News Publishing, 1987.
2. A listing of other books and audio-visual materials is detailed in Refrigeration and Air Conditioning I.
3. In the instructor's guide for Air Conditioning and Refrigeration Fundamentals, suggested supplemental materials are listed for each unit.

Competency:

1. Demonstrate the ability to pressurize a refrigeration system with dry nitrogen.
2. Demonstrate the ability to use soap bubbles, a halide torch, and an electronic leak detector to find a refrigerant leak.
3. Demonstrate the ability to vapor charge and liquid charge a refrigerant system.

Instructional Objectives:

1. Define terms related to pressurizing and leak testing.
2. Complete statements concerning safety rules for pressurizing a refrigeration system.
3. Identify steps for determining if a refrigerant leak exists.
4. Arrange in order the steps for pressurizing a refrigeration system.
5. Demonstrate the ability to leak check using soap bubbles.
6. Demonstrate the ability to leak check using a halide torch.
7. Demonstrate the ability to leak check using an electronic detector.
8. Demonstrate the ability to pressurize system with dry nitrogen and leak check the system.
9. Match terms related to charging with their definitions.
10. Complete statements concerning safety precautions for refrigerant handling.
11. Identify true statements concerning advantages and disadvantages of low side vapor charging.
12. List an advantage and disadvantage of high side liquid charging.
13. Demonstrate the ability to vapor charge using a charging cylinder.
14. Demonstrate the ability to vapor charge using a refrigerant cylinder.
15. Demonstrate the ability to liquid charge using a charging cylinder.
16. Demonstrate the ability to liquid charge using a refrigerant cylinder.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section G - Units I and II, "Pressurizing and Leak Testing," and "Charging" from Air Conditioning and Refrigeration Fundamentals.
2. Observe as your instructor demonstrates the proper techniques to use to pressurize, leak test, and charge a refrigeration system.
3. Read "The Refrigeration and Air Conditioning Troubleshooting Checklist."
4. View the videotape "Test and Maintenance Equipment" (Industrial Training Corporation).
5. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.

Application Exercises:

1. Leak check using soap bubbles.
2. Leak check using a halide torch.
3. Leak check using an electronic detector.
4. Pressurize system with dry nitrogen and leak check.
5. Vapor charge using a charging cylinder.
6. Vapor charge using a refrigerant cylinder.
7. Liquid charge using a charging cylinder.
8. Liquid charge using a refrigerant cylinder.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Equipment necessary to demonstrate the proper techniques to use to pressurize, leak test, and charge a refrigeration system.
2. A few of the companies that manufacture Air Conditioning and Refrigeration Trainers are listed in Refrigeration and Air Conditioning I.
3. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. Job sheets for the exercises for this unit are in the Air Conditioning and Refrigeration Fundamentals manual. The job sheets detail the procedure. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

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2. A copy of "The Refrigeration and Air Conditioning Troubleshooting Checklist" is included with this unit.

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Audio-Visual Materials:

1. The videotape "Test and Maintenance Equipment" is available from Industrial Training Corporation. The videotape covers temperature sensors, pressure gauges, gauge manifold, leak detecting procedures using leak detectors, vacuum pumps, and vacuum gauges. A workbook, instructor's guide, and overhead transparencies are included.

Resources:

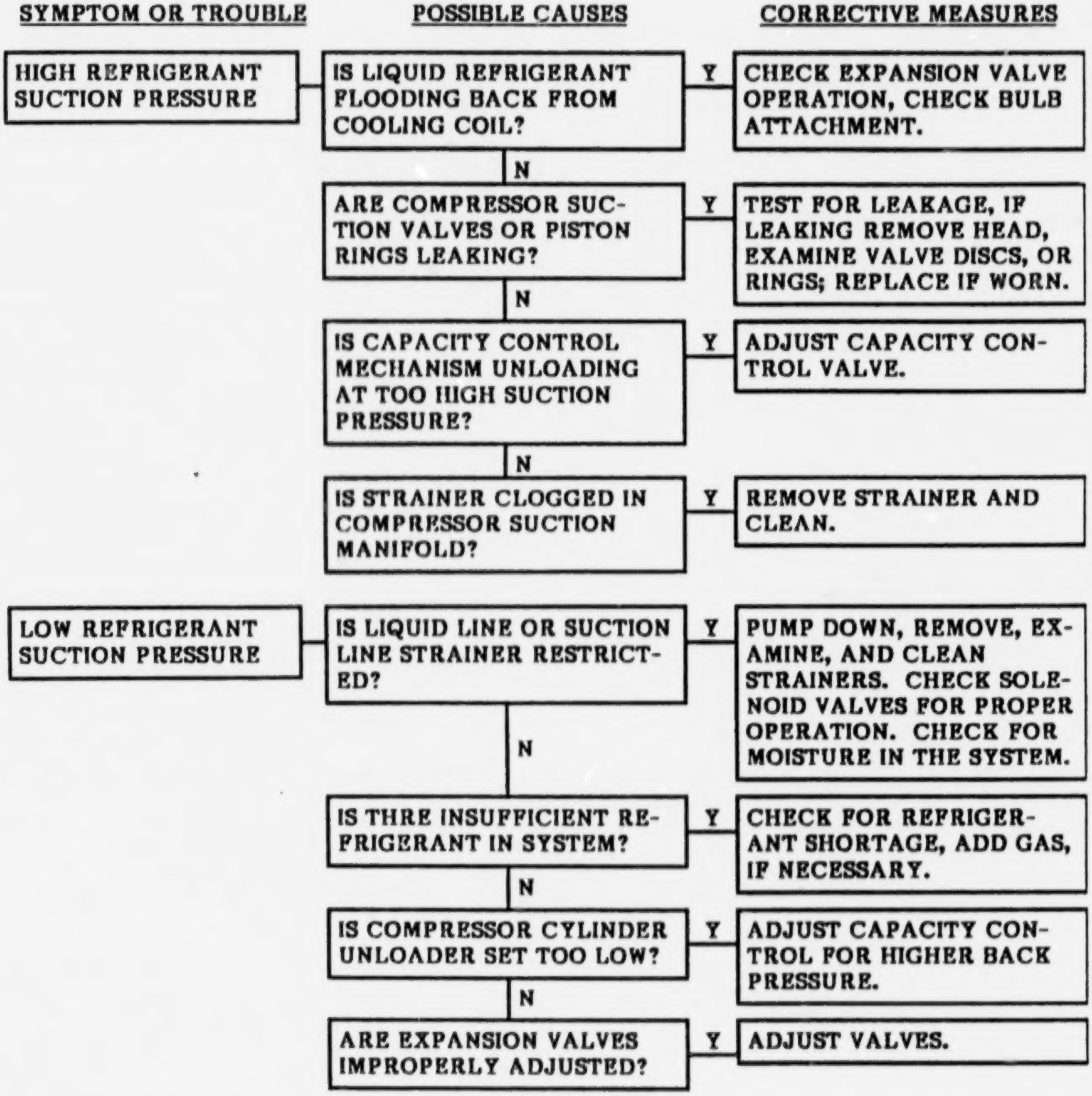
1. Books:
    A. Aglow, S., Schematic Wiring Simplified. Troy, Michigan: Business News Publishing, 1982.
    B. Russell, A., Understanding Schematic Wiring. Troy, Michigan: Business News Publishing, 1982.
    C. Aglow, S., Electronic HVAC Controls Simplified. Troy, Michigan: Business News Publishing, 1984.
    D. Service Hotline Handbooks, v. 1, 2, and 3. Troy, Michigan: Business News Publishing, 1983.
    E. A/C and Refrigeration System Servicing. Troy, Michigan: Business News Publishing, 1978.

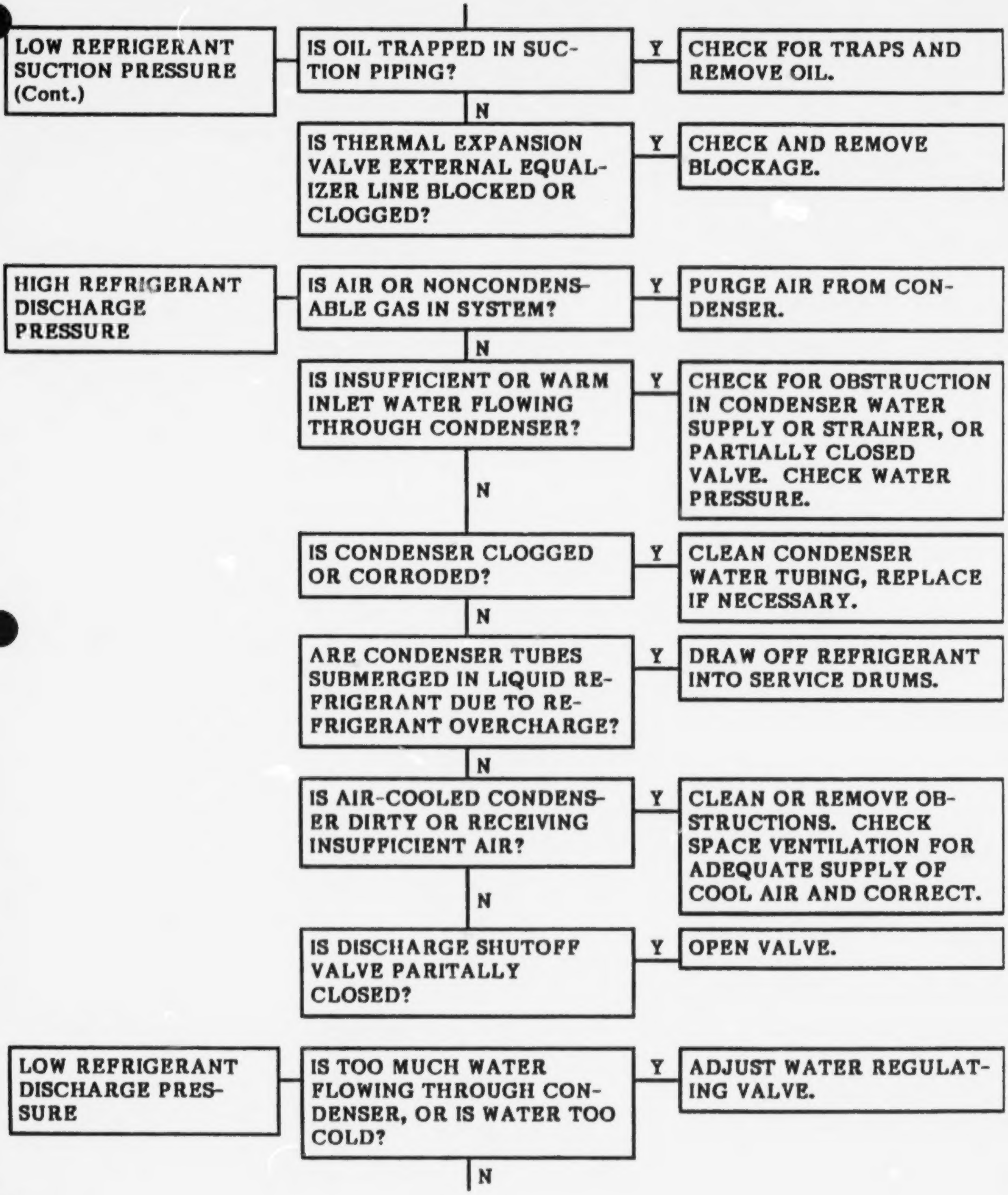
2. Audio-Visual Materials:
    A. "System Operation - Checks," "Mechanical Troubleshooting," "Electrical Controls and Circuits," and "Electrical Troubleshooting" all deal with air conditioning and refrigeration and are available from Industrial Training Corporation.
    B. "GTR-13A Charging and Discharging Systems" slide/cassette, Carrier Air Conditioning, Carrier Parkway, Syracuse, New York 13221.

3. Manuals:
    A. "Instruction Manual - Charging and Testing Manifold" and "The Henry Valve UK-90 Acid Test Kit" available from Henry Valve Company, 3215 North Avenue, Melrose Park, IL 60160, (312) 344-1100. Contact Paul Schwarz, Marketing Manager.

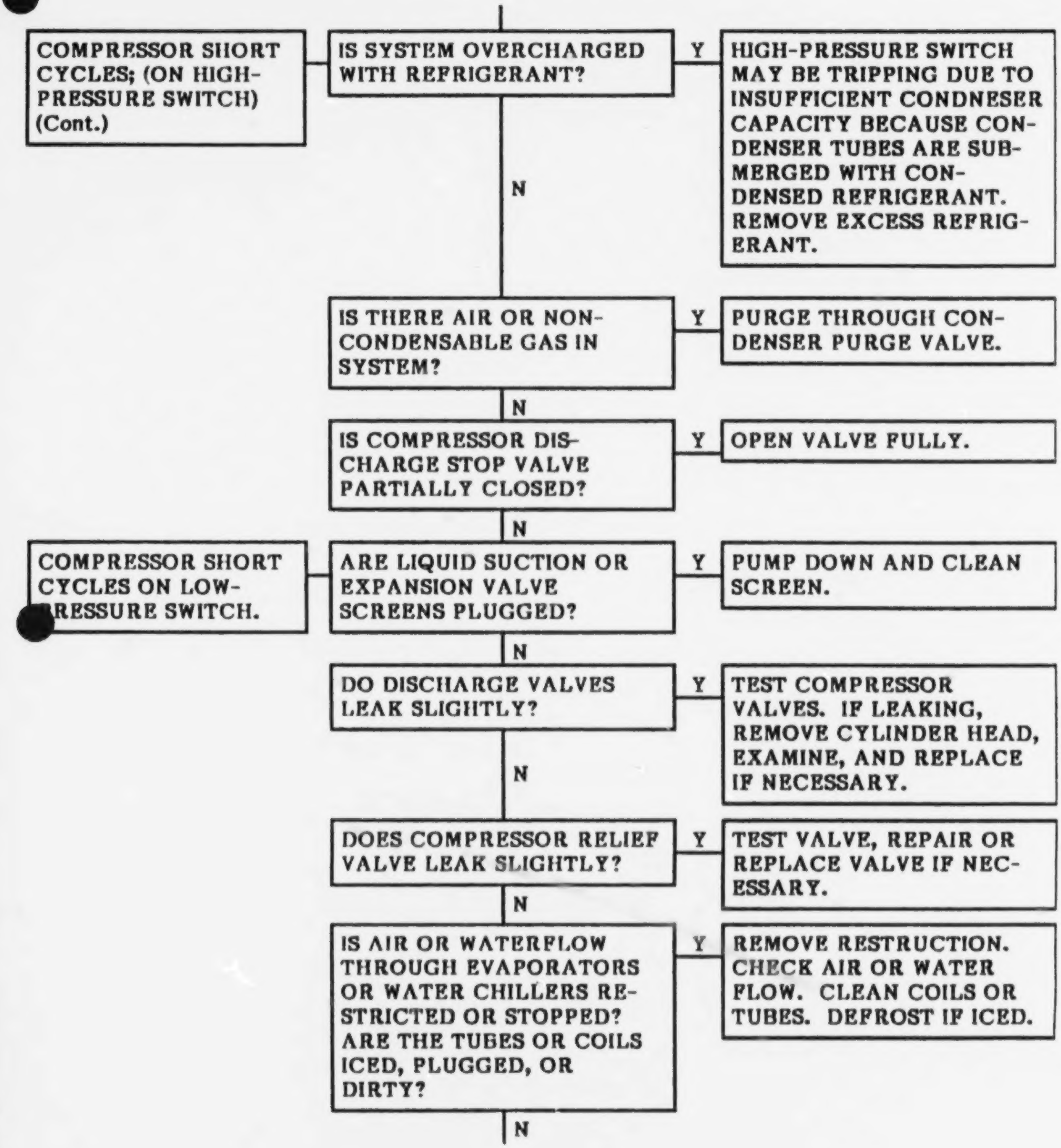
4. A listing of other books and audio-visual materials is detailed in Refrigeration and Air Conditioning I.
5. In the instructor's guide for Air Conditioning and Refrigeration Fundamentals, suggested supplemental materials are listed for each unit.

THE REFRIGERATION AND AIR CONDITIONING TROUBLESHOOTING CHECKLIST


SYMPTOM OR TROUBLE
POSSIBLE CAUSES
CORRECTIVE MEASURES
HIGH REFRIGERANT SUCTION PRESSURE
IS LIQUID REFRIGERANT FLOODING BACK FROM COOLING COIL?
Y
CHECK EXPANSION VALVE OPERATION, CHECK BULB ATTACHMENT.
N
ARE COMPRESSOR SUCTION VALVES OR PISTON RINGS LEAKING?
Y
TEST FOR LEAKAGE, IF LEAKING REMOVE HEAD, EXAMINE VALVE DISCS, OR RINGS; REPLACE IF WORN.
N
IS CAPACITY CONTROL MECHANISM UNLOADING AT TOO HIGH SUCTION PRESSURE?
Y
ADJUST CAPACITY CONTROL VALVE.
N
IS STRAINER CLOGGED IN COMPRESSOR SUCTION MANIFOLD?
Y
REMOVE STRAINER AND CLEAN.
LOW REFRIGERANT SUCTION PRESSURE
IS LIQUID LINE OR SUCTION LINE STRAINER RESTRICTED?
Y
PUMP DOWN, REMOVE, EXAMINE, AND CLEAN STRAINERS. CHECK SOLENOID VALVES FOR PROPER OPERATION. CHECK FOR MOISTURE IN THE SYSTEM.
N
IS THRE INSUFFICIENT REFRIGERANT IN SYSTEM?
Y
CHECK FOR REFRIGERANT SHORTAGE, ADD GAS, IF NECESSARY.
N
IS COMPRESSOR CYLINDER UNLOADER SET TOO LOW?
Y
ADJUST CAPACITY CONTROL FOR HIGHER BACK PRESSURE.
N
ARE EXPANSION VALVES IMPROPERLY ADJUSTED?
Y
ADJUST VALVES.


LOW REFRIGERANT SUCTION PRESSURE (Cont.)
IS OIL TRAPPED IN SUCTION PIPING?
Y
CHECK FOR TRAPS AND REMOVE OIL.
N
IS THERMAL EXPANSION VALVE EXTERNAL EQUALIZER LINE BLOCKED OR CLOGGED?
Y
CHECK AND REMOVE BLOCKAGE.
HIGH REFRIGERANT DISCHARGE PRESSURE
IS AIR OR NONCONDENSABLE GAS IN SYSTEM?
Y
PURGE AIR FROM CONDENSER.
N
IS INSUFFICIENT OR WARM INLET WATER FLOWING THROUGH CONDENSER?
Y
CHECK FOR OBSTRUCTION IN CONDENSER WATER SUPPLY OR STRAINER, OR PARTIALLY CLOSED VALVE. CHECK WATER PRESSURE.
N
IS CONDENSER CLOGGED OR CORRODED?
Y
CLEAN CONDENSER WATER TUBING, REPLACE IF NECESSARY.
N
ARE CONDENSER TUBES SUBMERGED IN LIQUID REFRIGERANT DUE TO REFRIGERANT OVERCHARGE?
Y
DRAW OFF REFRIGERANT INTO SERVICE DRUMS.
N
IS AIR-COOLED CONDENSER DIRTY OR RECEIVING INSUFFICIENT AIR?
Y
CLEAN OR REMOVE OBSTRUCTIONS. CHECK SPACE VENTILATION FOR ADEQUATE SUPPLY OF COOL AIR AND CORRECT.
N
IS DISCHARGE SHUTOFF VALVE PARITALLY CLOSED?
Y
OPEN VALVE.
LOW REFRIGERANT DISCHARGE PRESSURE
IS TOO MUCH WATER FLOWING THROUGH CONDENSER, OR IS WATER TOO COLD?
Y
ADJUST WATER REGULATING VALVE.
N

LOW REFRIGERANT DISCHARGE PRESSURE (Cont.)	IS LIQUID REFRIGERANT FLOODING BACK FROM EVAPORATOR?	Y	CHANGE EXPANSION VALVE ADJUSTMENT; EXAMINE FASTENING OF THERMAL BULB.
	N		
	IS COMPRESSOR DISCHARGE VALVE LEAKING?	Y	TEST WITH GAUGES, IF LEAKING, REPLACE.
	N		
	IS COMPRESSOR SUCTION STOP VALVE PARTIALLY CLOSED?	Y	OPEN VALVE.
	N		
	ARE COMPRESSOR SUCTION VALVES LEAKING?	Y	TEST FOR LEAKAGE, IF LEAKING REMOVE HEAD, EXAMINE VALVE DISCS; REPLACE IF WORN.
	N		
	ARE PISTON RINGS WORN?	Y	REPLACE, IF WORN.
COMPRESSOR SHORT CYCLES; (ON THERMAL MOTOR PROTECTOR: HERMETIC TYPE COMPRESSORS ONLY).	IS CONDENSER DIRTY?	Y	CLEAN. CHECK FOR AIR.
	N		
	IS VOLTAGE LOW?	Y	CHECK ELECTRICAL WIRING.
	N		
	IS SYSTEM PARTIALLY RESTRICTED?	Y	CHECK FOR MOISTURE IN CAPILLARY TUBE. INSERT DEHYDRATOR OR REPLACE.
COMPRESSOR SHORT CYCLES; (ON HIGH-PRESSURE SWITCH)	IS INSUFFICIENT WATER FLOWING THROUGH CONDENSER; IS CONDENSER CLOGGED?	Y	DETERMINE IF WATER HAS BEEN TURNED OFF. ADJUST WATER VALVE. CHECK FOR FOULED CONDENSER OR OBSTRUCTION IN WATER STRAINER.
	N		
	IS HIGH-PRESSURE SWITCH INCORRECTLY SET?	Y	CHECK SETTING OF HIGH-PRESSURE SWITCH.
	N		



COMPRESSOR SHORT CYCLES; (ON HIGH-PRESSURE SWITCH) (Cont.)

IS SYSTEM OVERCHARGED WITH REFRIGERANT?

HIGH-PRESSURE SWITCH MAY BE TRIPPING DUE TO INSUFFICIENT CONDNESER CAPACITY BECAUSE CONDENSER TUBES ARE SUBMERGED WITH CONDENSED REFRIGERANT. REMOVE EXCESS REFRIGERANT.

IS THERE AIR OR NONCONDENSABLE GAS IN SYSTEM?

PURGE THROUGH CONDENSER PURGE VALVE.

IS COMPRESSOR DISCHARGE STOP VALVE PARTIALLY CLOSED?

OPEN VALVE FULLY.

COMPRESSOR SHORT CYCLES ON LOW-PRESSURE SWITCH.

ARE LIQUID SUCTION OR EXPANSION VALVE SCREENS PLUGGED?

PUMP DOWN AND CLEAN SCREEN.

DO DISCHARGE VALVES LEAK SLIGHTLY?

TEST COMPRESSOR VALVES. IF LEAKING, REMOVE CYLINDER HEAD, EXAMINE, AND REPLACE IF NECESSARY.

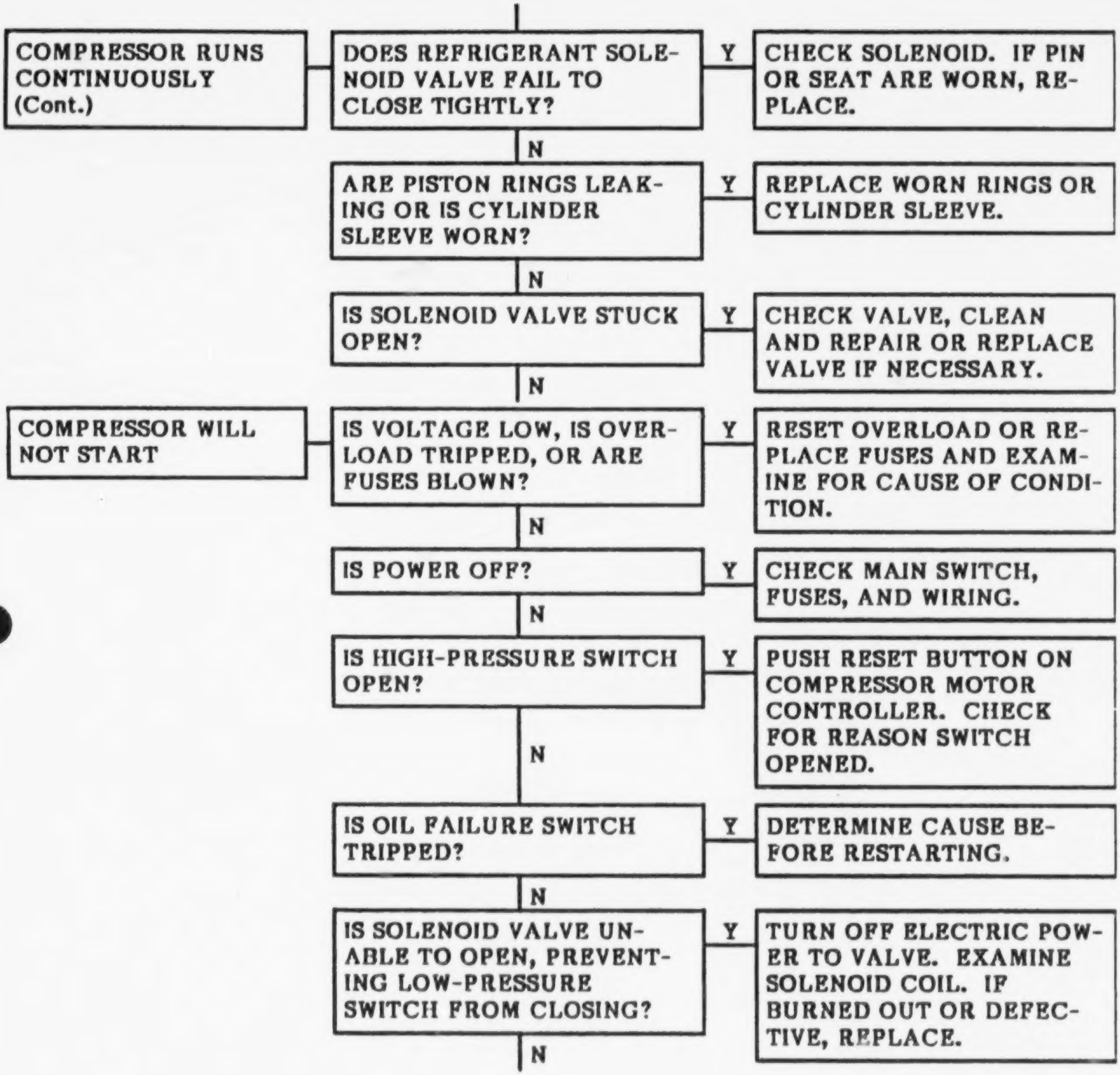
DOES COMPRESSOR RELIEF VALVE LEAK SLIGHTLY?

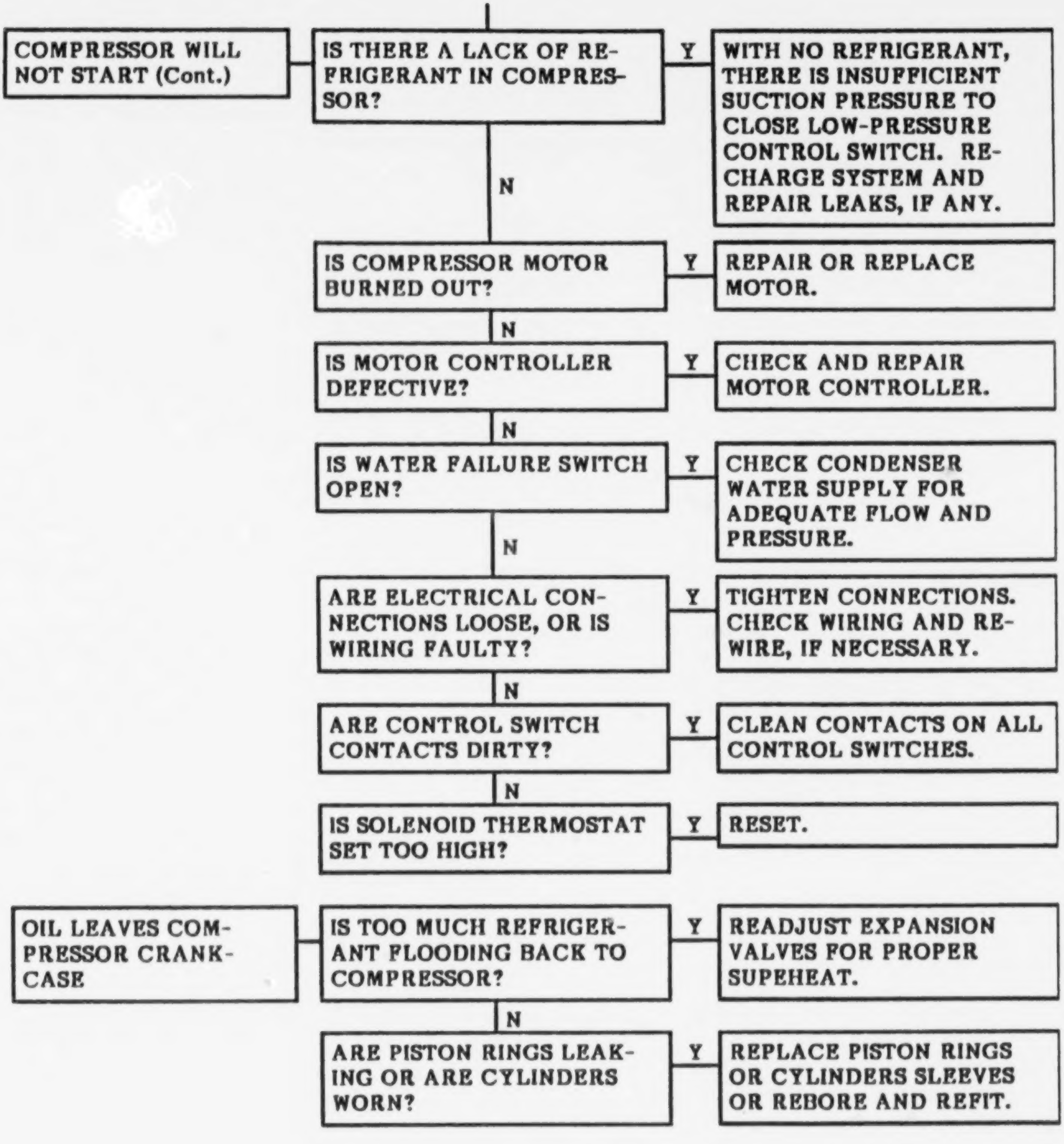
TEST VALVE, REPAIR OR REPLACE VALVE IF NECESSARY.

IS AIR OR WATERFLOW THROUGH EVAPORATORS OR WATER CHILLERS RESTRICTED OR STOPPED? ARE THE TUBES OR COILS ICED, PLUGGED, OR DIRTY?

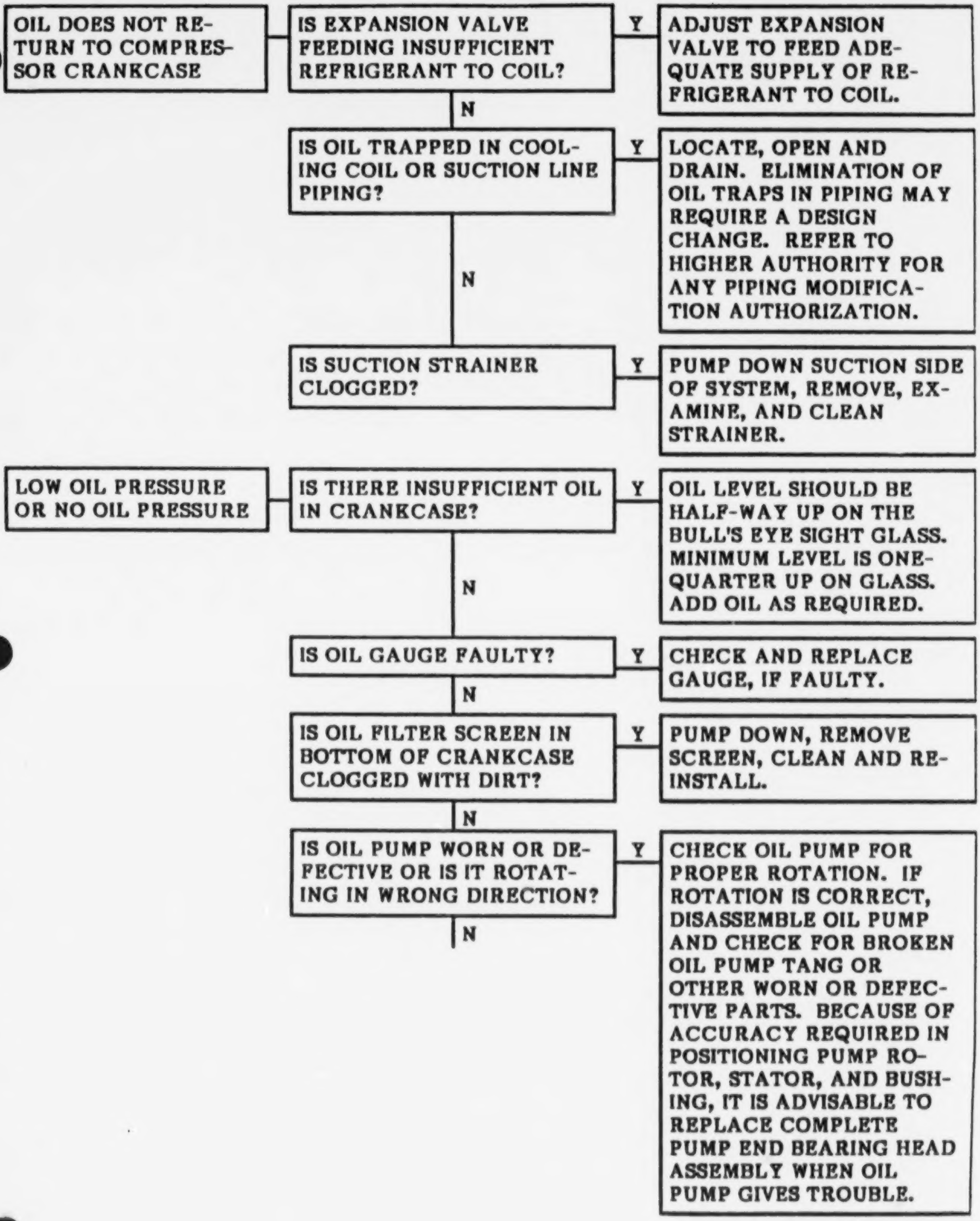
REMOVE RESTRUCTION. CHECK AIR OR WATER FLOW. CLEAN COILS OR TUBES. DEFROST IF ICED.

COMPRESSOR SHORT CYCLES ON LOW-PRESSURE SWITCH (Cont.)	HAS POWER ELEMENT ON EXPANSION VALVE LOST ITS CHARGE?	Y	DETACH THERMAL BULB FROM SUCTION LINE AND HOLD IN THE PALM OF ONE HAND, GRIPPING THE SUCTION LINE WITH THE OTHER HAND. IF FLOODING THROUGH IS OBSERVED, BULB HAS NOT LOST ITS CHARGE. IF NO FLOODING THROUGH IS NOTICED, REPAIR OR REPLACE WITH NEW EXPANSION VALVE OR PARTS.
	N		
	IS CAPACITY CONTROL MECHANISM SET TO UNLOAD AT TOO LOW A SUCTION PRESSURE.	Y	READJUST CAPACITY CONTROL VALVE.
	N		
	IS LOW-PRESSURE SWITCH SET TOO HIGH OR DEFECTIVE.	Y	RESET CONTROL CUTOUT AND CUT-IN SETTINGS. REPAIR OR REPLACE IF DEFECTIVE.
	N		
	IS THERE A SHORTAGE OF REFRIGERANT IN SYSTEM?	Y	CHECK FOR REFRIGERANT SHORTAGE, ADD REFRIGERANT, IF NECESSARY.
	N		
	IS SOLENOID VALVE LEAKING?	Y	CHECK FOR LEAKAGE, REPAIR OR REPLACE VALVE IF NECESSARY.
COMPRESSOR RUNS CONTINUOUSLY*	IS THERE A SHORTAGE OF REFRIGERANT?	Y	TEST FOR INSUFFICIENT REFRIGERANT; ADD PROPER AMOUNT. TEST FOR LEAKS.
	N		
	DOES DISCHARGE VALVE LEAK BADLY?	Y	TEST COMPRESSOR VALVE, IF LEAKING, REMOVE HEAD OF COMPRESSOR AND REPAIR OR REPLACE.
	N		


COMPRESSOR RUNS CONTINUOUSLY (Cont.)
DOES REFRIGERANT SOLENOID VALVE FAIL TO CLOSE TIGHTLY?
Y
CHECK SOLENOID. IF PIN OR SEAT ARE WORN, REPLACE.
N
ARE PISTON RINGS LEAKING OR IS CYLINDER SLEEVE WORN?
Y
REPLACE WORN RINGS OR CYLINDER SLEEVE.
N
IS SOLENOID VALVE STUCK OPEN?
Y
CHECK VALVE, CLEAN AND REPAIR OR REPLACE VALVE IF NECESSARY.
N
COMPRESSOR WILL NOT START
IS VOLTAGE LOW, IS OVERLOAD TRIPPED, OR ARE FUSES BLOWN?
Y
RESET OVERLOAD OR REPLACE FUSES AND EXAMINE FOR CAUSE OF CONDITION.
N
IS POWER OFF?
Y
CHECK MAIN SWITCH, FUSES, AND WIRING.
N
IS HIGH-PRESSURE SWITCH OPEN?
Y
PUSH RESET BUTTON ON COMPRESSOR MOTOR CONTROLLER. CHECK FOR REASON SWITCH OPENED.
N
IS OIL FAILURE SWITCH TRIPPED?
Y
DETERMINE CAUSE BEFORE RESTARTING.
N
IS SOLENOID VALVE UNABLE TO OPEN, PREVENTING LOW-PRESSURE SWITCH FROM CLOSING?
Y
TURN OFF ELECTRIC POWER TO VALVE. EXAMINE SOLENOID COIL. IF BURNED OUT OR DEFECTIVE, REPLACE.
N



COMPRESSOR WILL NOT START (Cont.)	IS THERE A LACK OF REFRIGERANT IN COMPRESSOR?	Y	WITH NO REFRIGERANT, THERE IS INSUFFICIENT SUCTION PRESSURE TO CLOSE LOW-PRESSURE CONTROL SWITCH. RECHARGE SYSTEM AND REPAIR LEAKS, IF ANY.
	N		
	IS COMPRESSOR MOTOR BURNED OUT?	Y	REPAIR OR REPLACE MOTOR.
	N		
	IS MOTOR CONTROLLER DEFECTIVE?	Y	CHECK AND REPAIR MOTOR CONTROLLER.
	N		
	IS WATER FAILURE SWITCH OPEN?	Y	CHECK CONDENSER WATER SUPPLY FOR ADEQUATE FLOW AND PRESSURE.
	N		
	ARE ELECTRICAL CONNECTIONS LOOSE, OR IS WIRING FAULTY?	Y	TIGHTEN CONNECTIONS. CHECK WIRING AND REWIRE, IF NECESSARY.
	N		
	ARE CONTROL SWITCH CONTACTS DIRTY?	Y	CLEAN CONTACTS ON ALL CONTROL SWITCHES.
	N		
	IS SOLENOID THERMOSTAT SET TOO HIGH?	Y	RESET.
OIL LEAVES COMPRESSOR CRANKCASE	IS TOO MUCH REFRIGERANT FLOODING BACK TO COMPRESSOR?	Y	READJUST EXPANSION VALVES FOR PROPER SUPEHEAT.
	N		
	ARE PISTON RINGS LEAKING OR ARE CYLINDERS WORN?	Y	REPLACE PISTON RINGS OR CYLINDERS SLEEVES OR REBORE AND REFIT.

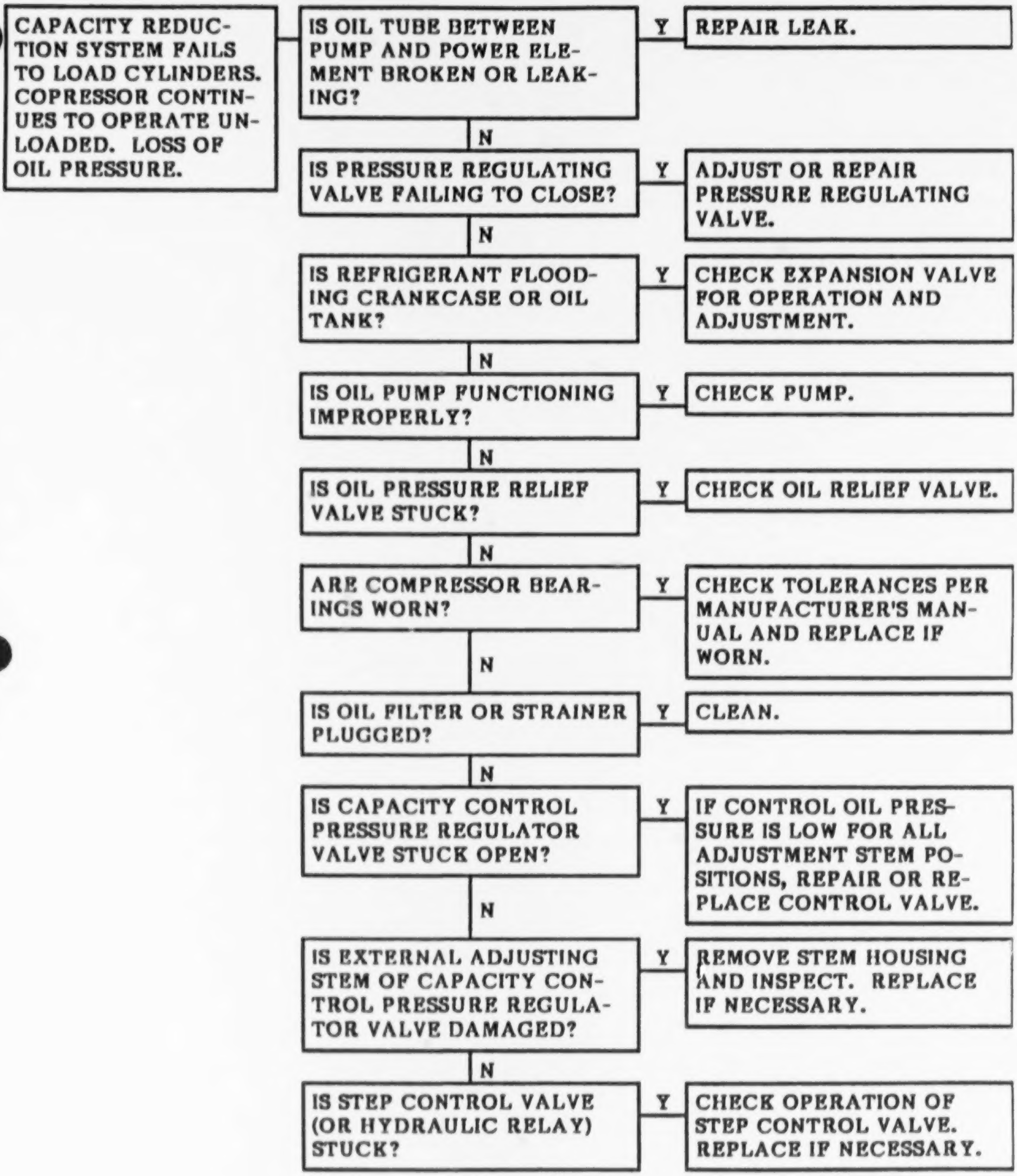


OIL DOES NOT RETURN TO COMPRESSOR CRANKCASE	IS EXPANSION VALVE FEEDING INSUFFICIENT REFRIGERANT TO COIL?	Y	ADJUST EXPANSION VALVE TO FEED ADEQUATE SUPPLY OF REFRIGERANT TO COIL.
	N		
	IS OIL TRAPPED IN COOLING COIL OR SUCTION LINE PIPING?	Y	LOCATE, OPEN AND DRAIN. ELIMINATION OF OIL TRAPS IN PIPING MAY REQUIRE A DESIGN CHANGE. REFER TO HIGHER AUTHORITY FOR ANY PIPING MODIFICATION AUTHORIZATION.
	N		
	IS SUCTION STRAINER CLOGGED?	Y	PUMP DOWN SUCTION SIDE OF SYSTEM, REMOVE, EXAMINE, AND CLEAN STRAINER.
LOW OIL PRESSURE OR NO OIL PRESSURE	IS THERE INSUFFICIENT OIL IN CRANKCASE?	Y	OIL LEVEL SHOULD BE HALF-WAY UP ON THE BULL'S EYE SIGHT GLASS. MINIMUM LEVEL IS ONE-QUARTER UP ON GLASS. ADD OIL AS REQUIRED.
	N		
	IS OIL GAUGE FAULTY?	Y	CHECK AND REPLACE GAUGE, IF FAULTY.
	N		
	IS OIL FILTER SCREEN IN BOTTOM OF CRANKCASE CLOGGED WITH DIRT?	Y	PUMP DOWN, REMOVE SCREEN, CLEAN AND REINSTALL.
	N		
	IS OIL PUMP WORN OR DEFECTIVE OR IS IT ROTATING IN WRONG DIRECTION?	Y	CHECK OIL PUMP FOR PROPER ROTATION. IF ROTATION IS CORRECT, DISASSEMBLE OIL PUMP AND CHECK FOR BROKEN OIL PUMP TANG OR OTHER WORN OR DEFECTIVE PARTS. BECAUSE OF ACCURACY REQUIRED IN POSITIONING PUMP ROTOR, STATOR, AND BUSHING, IT IS ADVISABLE TO REPLACE COMPLETE PUMP END BEARING HEAD ASSEMBLY WHEN OIL PUMP GIVES TROUBLE.
	N		

LOW OIL PRESSURE OR NO OIL PRESSURE (Cont.)	IS OIL PIPING FAULTY OR OIL LINE CLOGGED?	Y	CHECK OIL PIPING TO OIL PRESSURE SWITCH AND GAUGE. CHECK OIL PIPING IN COMPRESSOR CRANKCASE. CLEAN, REPAIR OR REPLACE PIPING.
	N		
	IS OIL PRESSURE REGULATOR (RELIEF VALVE) DEFECTIVE?	Y	OIL PRESSURE REGULATOR ON SIDE OF CRANKCASE IS NONADJUSTABLE. REMOVE, CHECK AND REPLACE IF REQUIRED.
	N		
	ARE COMPRESSOR BEARINGS WORN?	Y	REPLACE WORN BEARINGS.
COMPRESSOR CUT OUT ON LOW OIL PRESSURE	IS OIL PRESSURE LOW? REFER TO LOW OIL PRESSURE PARAGRAPH ABOVE.	Y	RESTORE NORMAL OIL PRESSURE. REFER TO LOW OIL PRESSURE PARAGRAPH ABOVE.
	N		
	IS OIL PRESSURE SAFETY SWITCH INCORRECTLY SET OR DEFECTIVE?	Y	CHECK SWITCH CUT-IN AND CUT-OUT SETTINGS. RESET OR REPLACE SWITCH.
COMPRESSOR NOISY	ARE HOLD DOWN BOLTS LOOSE?	Y	TIGHTEN BOLTS.
	N		
	IS PIPING IMPROPERLY SUPPORTED OR ISOLATED?	Y	CHECK PIPING, SUPPORT FIRMLY WITH SUITABLE HANGARS.
	N		
	IS COMPRESSOR DRIVE IMPROPERLY ALIGNED, LOOSE, OR WORN?	Y	CHECK ALIGNMENT FOR LOOSE OR WORN PARTS. REPLACE PARTS, IF WORN.
	N		

COMPRESSOR NOISY (Cont.)	IS COMPRESSOR SLUGGING DUE TO FLOODING BACK OF REFRIGERANT?	Y	EXPANSION VALVE OPEN TOO WIDE; CLOSE. THERMAL BULB INCORRECTLY PLACED OR LOOSE. CHECK.
	N		
	ARE PARTS SUCH AS PISTON PINS, CONNECTING ROD BEARINGS, AND SO FORTH, SHOWING WEAR?	Y	DETERMINE CAUSE, REPAIR COMPRESSOR PARTS AFFECTED.
	N		
	IS CLEARANCE INSUFFICIENT BETWEEN PISTON AND VALVE PLATE INDICATED BY A SHARP, MEDIUM PITCHED METALLIC HAMMER AS CYLINDER IS UNLOADED?	Y	REPLACE OVER TOLERANCE PARTS.
	N		
	ARE MOTOR OR COMPRESSOR BEARINGS WORN?	Y	REPLACE WORN BEARINGS.
	N		
	IS EXCESS OIL IN CIRCULATION CAUSING HYDRAULIC KNOCK?	Y	REMOVE EXCESS OIL, CHECK FOR FLOODBACK.
	N		
	DOES NOISE LEVEL VARY WITH UNLOADING DUE TO DEFECTIVE VALVE LIFTER MECHANISM?	Y	REFER TO CAPACITY CONTROL TROUBLE PARAGRAPHS BELOW.
COMPRESSOR CRANKCASE SWEATING OR COLD	IS LIQUID REFRIGERANT RETURNING TO COMPRESSOR?	Y	EXAMINE THERMAL EXPANSION VALVE FOR PROPER ADJUSTMENT. SEE THAT HAND EXPANSION VALVE IS CLOSED.
	N		
	IS THERE A REFRIGERANT OVERCHARGE?	Y	REMOVE EXCESS REFRIGERANT.
	N		

COMPRESSOR CRANKCASE SWEATING OR COLD (Cont.)	IS TOO MUCH OIL IN CIRCULATION?	REMOVE EXCESS OIL. OIL LEVEL TO BE NO HIGHER THAN HALF-WAY UP BULL'S EYE SIGHT GLASS.
HIGH CRANKCASE TEMPERATURE	IS SUPERHEAT EXCESSIVE?	RESET THERMAL EXPANSION VALVE TO CURRECT SUPERHEAT.
	ARE SUCTION VALVES OR DISCHARGE VALVES LEAKING?	PUMP DOWN, REMOVE CYLINDER HEADS, AND EXAMINE SUCTION AND DISCHARGE VALVES. REPLACE IF NECESSARY.
PIPE RATTLE	IS PIPING INADEQUATELY SUPPORTED OR ARE PIPE CONNECTIONS LOOSE?	SUPPORT PIPES OR CHECK PIPE CONNECTIONS.
HISSING AT EXPANSION VALVE	IS THERE INSUFFICIENT REFRIGERANT FLOW THROUGH EXPANSION VALVES?	CHECK EXPANSION VALVE ADJUSTMENT. REFRIGERANT MAY BE LOW, ADD IF NECESSARY. CHECK LINE VALVES, STRAINERS FOR OBSTRUCTION CAUSING PRESSURE LOSS AND RESULTING REFRIGERANT FLASHING.
CAPACITY REDUCTION SYSTEM FAILS TO UNLOAD CYLINDERS. COMPRESSOR CONTINUES TO OPERATE AT FULL OR PARTIAL LOAD.	IS CAPACITY CONTROL PRESSURE REGULATOR VALVE INOPERATIVE?	REPAIR OR REPLACE.
	IS EXTERNAL ADJUSTING STEM OF CAPACITY CONTROL PRESSURE REGULATOR VALVE DAMAGED?	REMOVE STEM HOUSING AND INSPECT. REPLACE IF NECESSARY.
	IS STEP CONTROL VALVE (OR HYDRAULIC RELAY) STUCK?	CHECK OPERATION OF STEP CONTROL VALVE. REPLACE IF NECESSARY.
	IS SUCTION PRESSURE REGULATING VALVE FAILING TO OPEN?	ADJUST OR REPAIR PRESSURE REGULATING VALVE.



CAPACITY REDUCTION SYSTEM FAILS TO LOAD CYLINDERS. COPRESSOR CONTINUES TO OPERATE UNLOADED. LOSS OF OIL PRESSURE.

IS OIL TUBE BETWEEN PUMP AND POWER ELEMENT BROKEN OR LEAKING? Y: REPAIR LEAK.

N

IS PRESSURE REGULATING VALVE FAILING TO CLOSE? Y: ADJUST OR REPAIR PRESSURE REGULATING VALVE.

N

IS REFRIGERANT FLOODING CRANKCASE OR OIL TANK? Y: CHECK EXPANSION VALVE FOR OPERATION AND ADJUSTMENT.

N

IS OIL PUMP FUNCTIONING IMPROPERLY? Y: CHECK PUMP.

N

IS OIL PRESSURE RELIEF VALVE STUCK? Y: CHECK OIL RELIEF VALVE.

N

ARE COMPRESSOR BEARINGS WORN? Y: CHECK TOLERANCES PER MANUFACTURER'S MANUAL AND REPLACE IF WORN.

N

IS OIL FILTER OR STRAINER PLUGGED? Y: CLEAN.

N

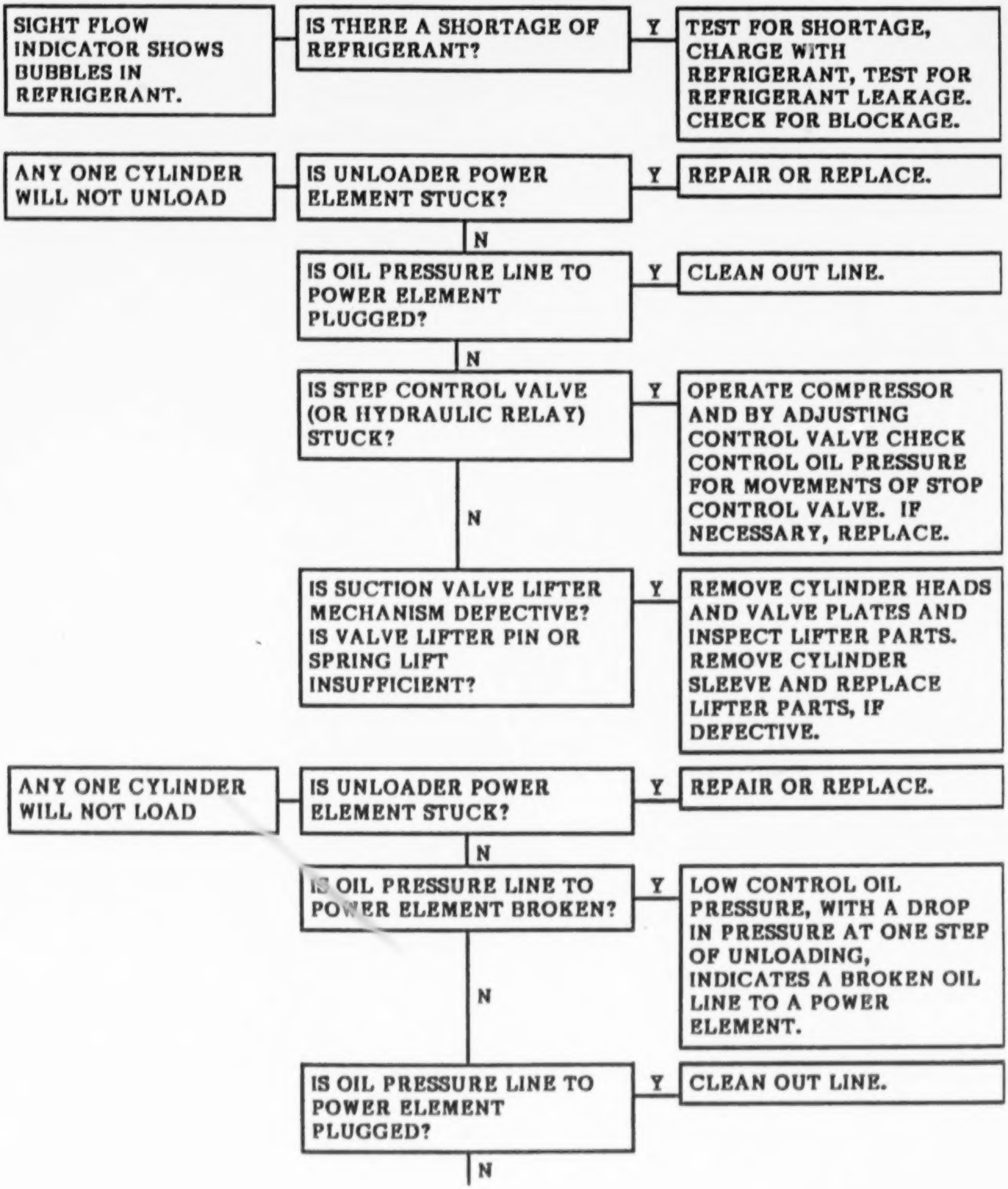
IS CAPACITY CONTROL PRESSURE REGULATOR VALVE STUCK OPEN? Y: IF CONTROL OIL PRESSURE IS LOW FOR ALL ADJUSTMENT STEM POSITIONS, REPAIR OR REPLACE CONTROL VALVE.

N

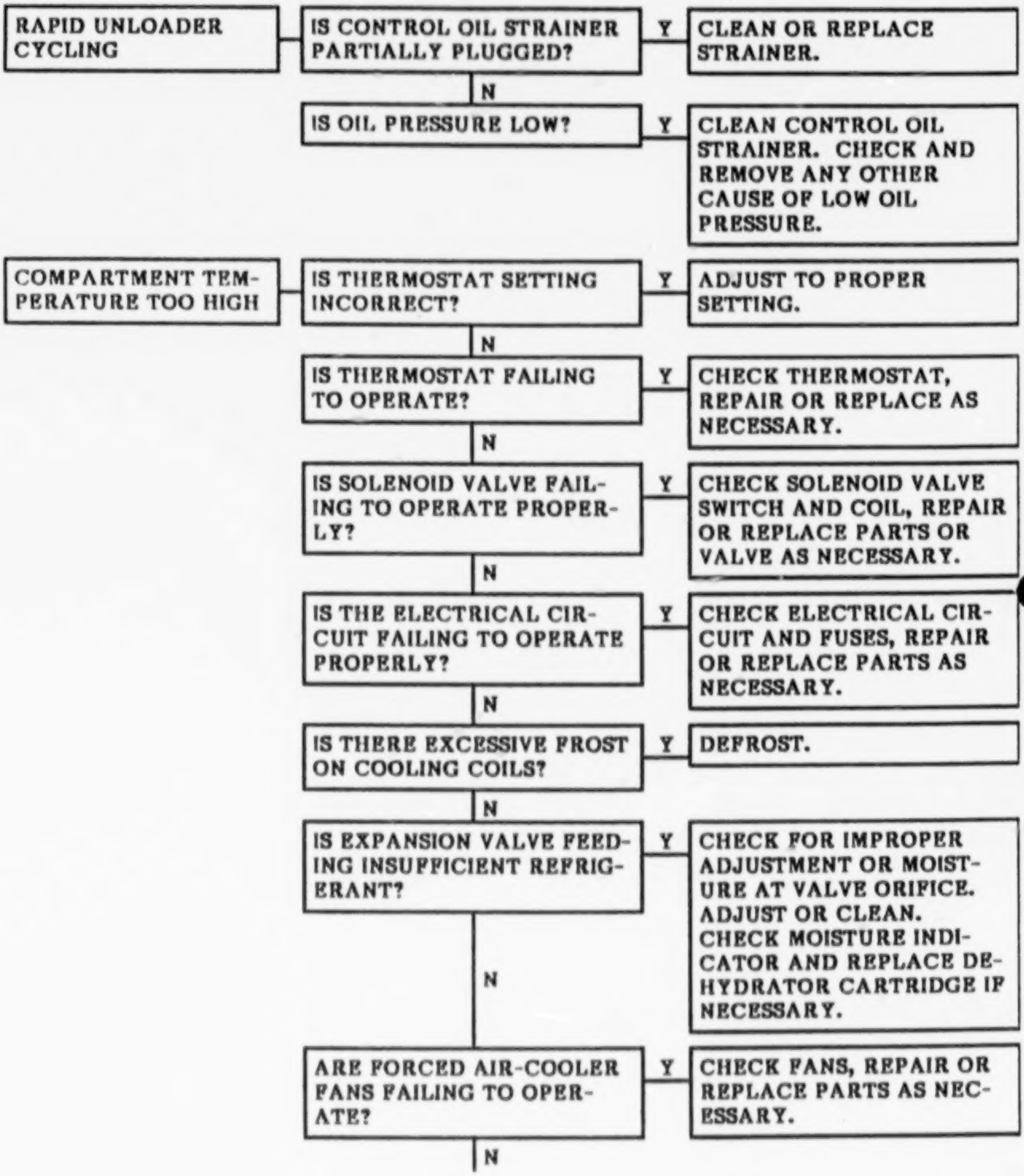
IS EXTERNAL ADJUSTING STEM OF CAPACITY CONTROL PRESSURE REGULATOR VALVE DAMAGED? Y: REMOVE STEM HOUSING AND INSPECT. REPLACE IF NECESSARY.

N

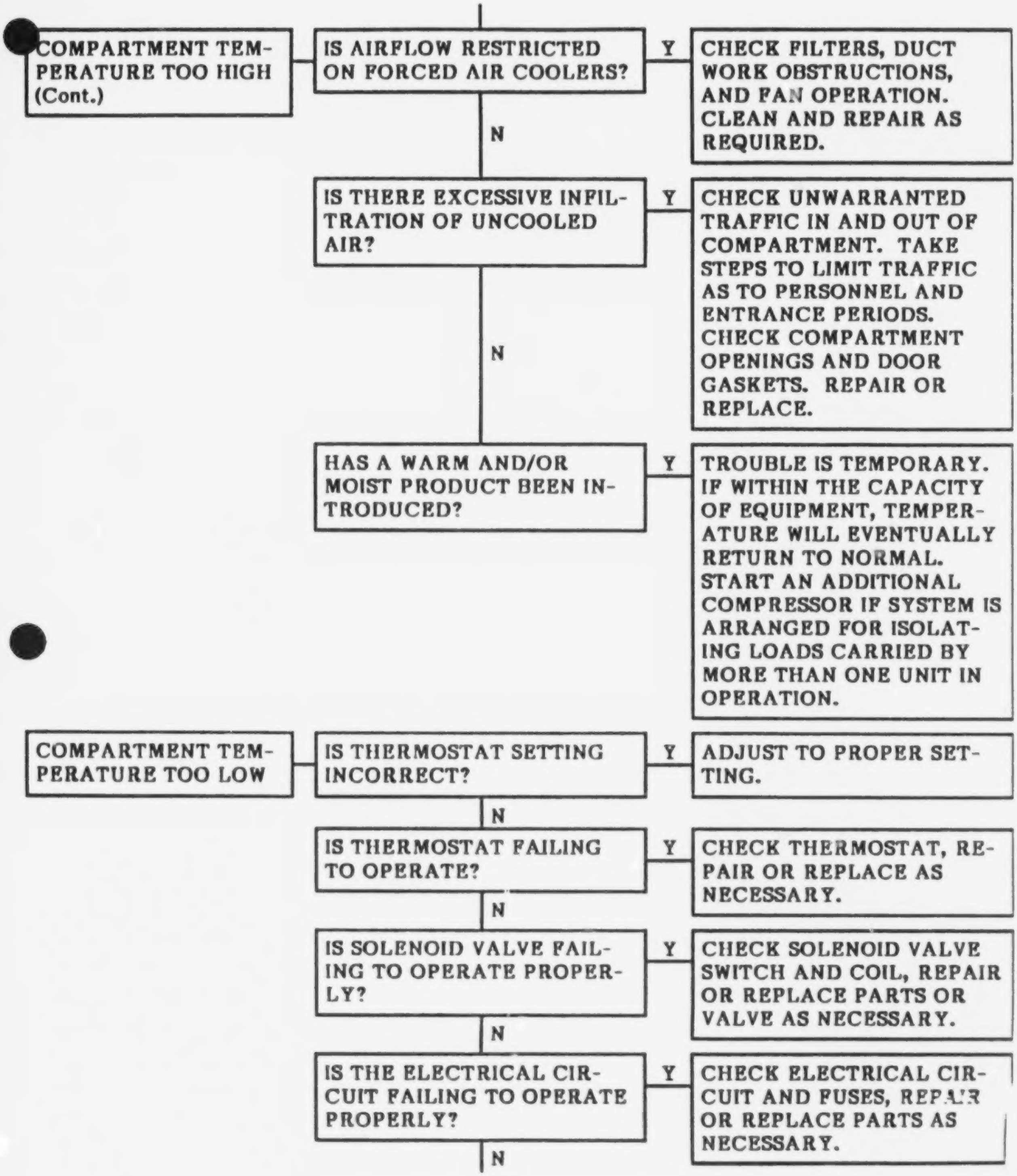
IS STEP CONTROL VALVE (OR HYDRAULIC RELAY) STUCK? Y: CHECK OPERATION OF STEP CONTROL VALVE. REPLACE IF NECESSARY.


SIGHT FLOW INDICATOR SHOWS BUBBLES IN REFRIGERANT.
IS THERE A SHORTAGE OF REFRIGERANT?
Y
TEST FOR SHORTAGE, CHARGE WITH REFRIGERANT, TEST FOR REFRIGERANT LEAKAGE. CHECK FOR BLOCKAGE.
ANY ONE CYLINDER WILL NOT UNLOAD
IS UNLOADER POWER ELEMENT STUCK?
Y
REPAIR OR REPLACE.
N
IS OIL PRESSURE LINE TO POWER ELEMENT PLUGGED?
Y
CLEAN OUT LINE.
N
IS STEP CONTROL VALVE (OR HYDRAULIC RELAY) STUCK?
Y
OPERATE COMPRESSOR AND BY ADJUSTING CONTROL VALVE CHECK CONTROL OIL PRESSURE FOR MOVEMENTS OF STOP CONTROL VALVE. IF NECESSARY, REPLACE.
N
IS SUCTION VALVE LIFTER MECHANISM DEFECTIVE? IS VALVE LIFTER PIN OR SPRING LIFT INSUFFICIENT?
Y
REMOVE CYLINDER HEADS AND VALVE PLATES AND INSPECT LIFTER PARTS. REMOVE CYLINDER SLEEVE AND REPLACE LIFTER PARTS, IF DEFECTIVE.
ANY ONE CYLINDER WILL NOT LOAD
IS UNLOADER POWER ELEMENT STUCK?
Y
REPAIR OR REPLACE.
N
IS OIL PRESSURE LINE TO POWER ELEMENT BROKEN?
Y
LOW CONTROL OIL PRESSURE, WITH A DROP IN PRESSURE AT ONE STEP OF UNLOADING, INDICATES A BROKEN OIL LINE TO A POWER ELEMENT.
N
IS OIL PRESSURE LINE TO POWER ELEMENT PLUGGED?
Y
CLEAN OUT LINE.
N

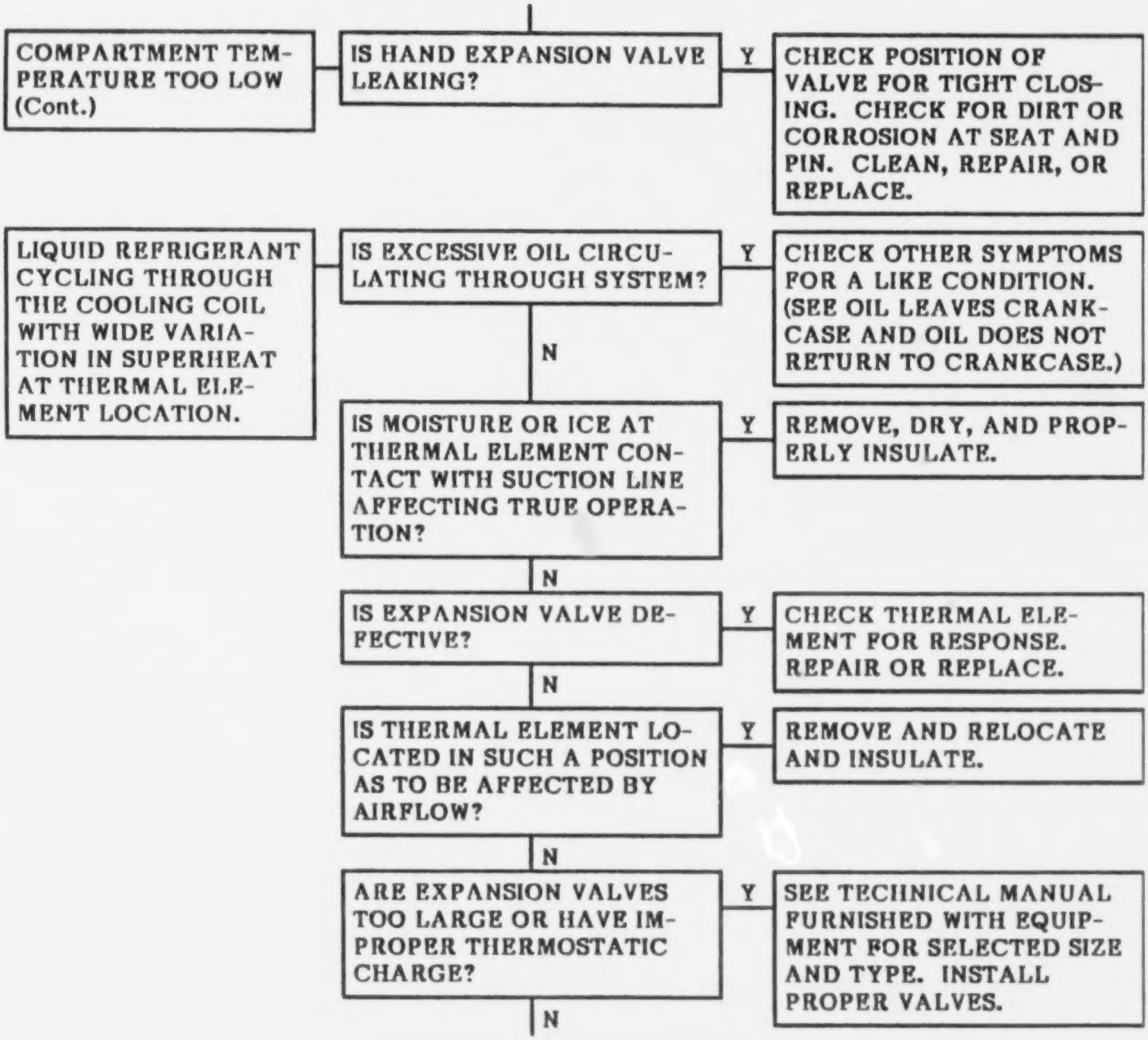
ANY ONE CYLINDER WILL NOT LOAD (Cont.)	IS VALVE LIFTER MECHANISM DEFECTIVE? DO LIFTER PINS AND SPRINGS FAIL TO RETRACT BELOW VALVE SEATS?	Y	REMOVE CYLINDER HEADS AND VALVE PLATES. SECURE CYLINDER SLEEVES. OPERATE COMPRESSOR AND BY ADJUSTING CONTROL VALVE CHECK THAT LIFTER PINS AND SPRINGS RETRACT BELOW VALVE SEATS. REMOVE CYLINDER SLEEVE AND REPLACE LIFTER PARTS, IF DEFECTIVE. REMOVE SLEEVE, PISTON, AND CONNECTING ROD AND REPLACE UNLOADER POWER ELEMENT, IF DEFECTIVE.
COMPRESSOR NOISE VARYING WITH UNLOADING.	ARE VALVE LIFTER PINS STUCK?	Y	CHECK AND REPLACE STUCK LIFTER PINS.
	N		
	IS UNLOADER POWER ELEMENT PISTON STUCK?	Y	REPAIR OR REPLACE.
	N		
	IS UNLOADER POWER ELEMENT FORK OR SLEEVE MISALIGNED?	Y	REALIGN OR REPLACE.
	N		
	IS OIL PRESSURE LINE AT CONNECTION TO UNLOADER POWER ELEMENT LEAKING?	Y	REPAIR LEAKING LINE.
	N		
	IS STEP CONTROL VALVE (OR HYDRAULIC RELAY) SLUGGISH? IS THERE VALVE HAMMER OR CLATTER WHEN CYLINDER IS LOADED OR UNLOADED?	Y	CHECK CONTROL OIL PRESSURE. SHOULD DIP ABRUPTLY WHEN CYLINDER UNLOADS. IF DIP IS NOT ABRUPT, REPLACE CONTROL COVER ASSEMBLY.
	N		
	IS THERE INSUFFICIENT OIL PRESSURE? IS VALVE CLATTER INCREASED AND STEADY WHEN CYLINDER IS UNLOADED?	Y	CLEAN CONTROL OIL STRAINER. CHECK AND REMOVE ANY OTHER CAUSE OF LOW OIL PRESSURE.



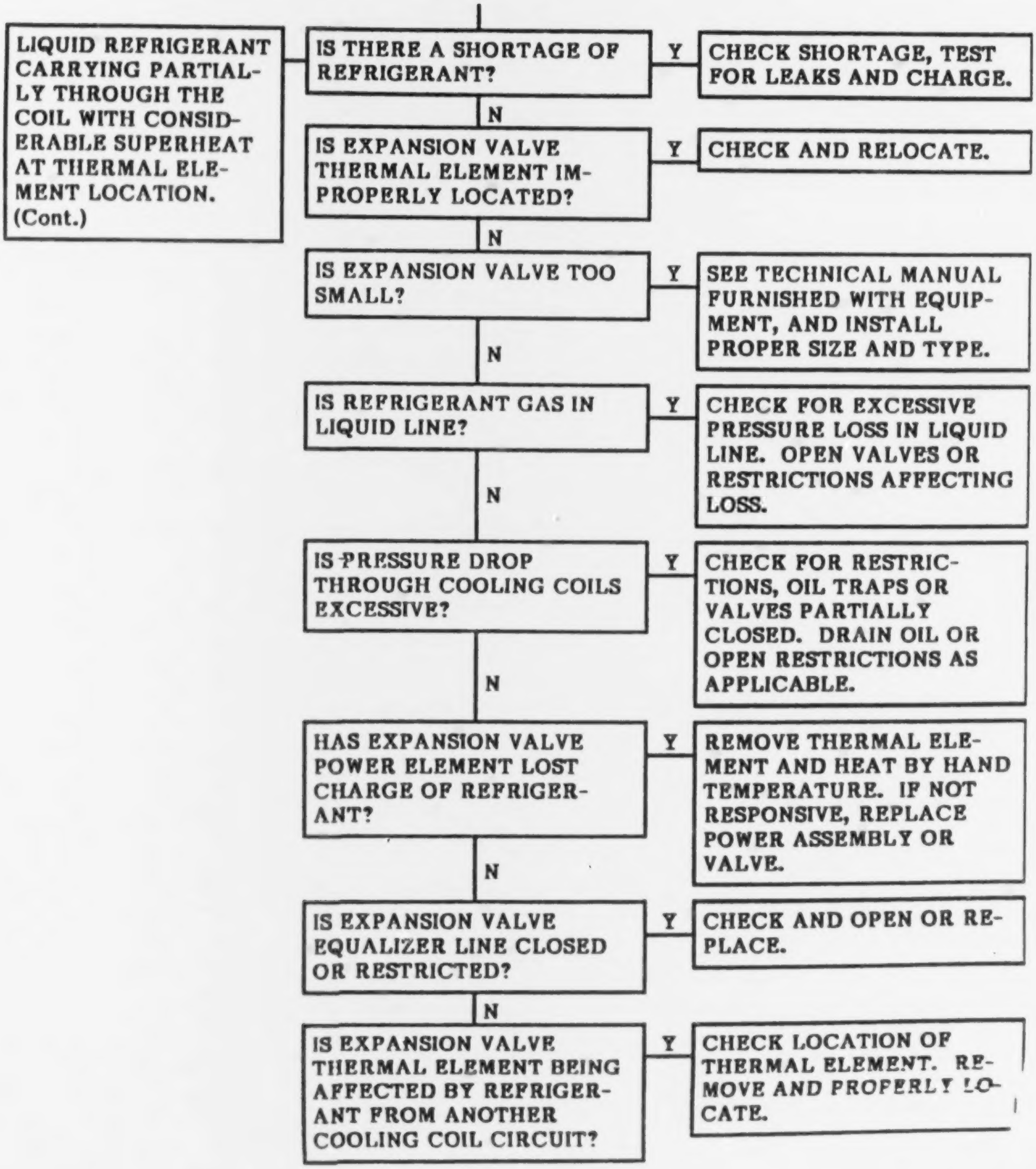
RAPID UNLOADER CYCLING	IS CONTROL OIL STRAINER PARTIALLY PLUGGED?	Y	CLEAN OR REPLACE STRAINER.
	N		
	IS OIL PRESSURE LOW?	Y	CLEAN CONTROL OIL STRAINER. CHECK AND REMOVE ANY OTHER CAUSE OF LOW OIL PRESSURE.
COMPARTMENT TEMPERATURE TOO HIGH	IS THERMOSTAT SETTING INCORRECT?	Y	ADJUST TO PROPER SETTING.
	N		
	IS THERMOSTAT FAILING TO OPERATE?	Y	CHECK THERMOSTAT, REPAIR OR REPLACE AS NECESSARY.
	N		
	IS SOLENOID VALVE FAILING TO OPERATE PROPERLY?	Y	CHECK SOLENOID VALVE SWITCH AND COIL, REPAIR OR REPLACE PARTS OR VALVE AS NECESSARY.
	N		
	IS THE ELECTRICAL CIRCUIT FAILING TO OPERATE PROPERLY?	Y	CHECK ELECTRICAL CIRCUIT AND FUSES, REPAIR OR REPLACE PARTS AS NECESSARY.
	N		
	IS THERE EXCESSIVE FROST ON COOLING COILS?	Y	DEFROST.
	N		
	IS EXPANSION VALVE FEEDING INSUFFICIENT REFRIGERANT?	Y	CHECK FOR IMPROPER ADJUSTMENT OR MOISTURE AT VALVE ORIFICE. ADJUST OR CLEAN. CHECK MOISTURE INDICATOR AND REPLACE DEHYDRATOR CARTRIDGE IF NECESSARY.
	N		
	ARE FORCED AIR-COOLER FANS FAILING TO OPERATE?	Y	CHECK FANS, REPAIR OR REPLACE PARTS AS NECESSARY.
	N		



COMPARTMENT TEMPERATURE TOO HIGH (Cont.)	IS AIRFLOW RESTRICTED ON FORCED AIR COOLERS?	Y	CHECK FILTERS, DUCT WORK OBSTRUCTIONS, AND FAN OPERATION. CLEAN AND REPAIR AS REQUIRED.
	N		
	IS THERE EXCESSIVE INFILTRATION OF UNCOOLED AIR?	Y	CHECK UNWARRANTED TRAFFIC IN AND OUT OF COMPARTMENT. TAKE STEPS TO LIMIT TRAFFIC AS TO PERSONNEL AND ENTRANCE PERIODS. CHECK COMPARTMENT OPENINGS AND DOOR GASKETS. REPAIR OR REPLACE.
	N		
	HAS A WARM AND/OR MOIST PRODUCT BEEN INTRODUCED?	Y	TROUBLE IS TEMPORARY. IF WITHIN THE CAPACITY OF EQUIPMENT, TEMPERATURE WILL EVENTUALLY RETURN TO NORMAL. START AN ADDITIONAL COMPRESSOR IF SYSTEM IS ARRANGED FOR ISOLATING LOADS CARRIED BY MORE THAN ONE UNIT IN OPERATION.
COMPARTMENT TEMPERATURE TOO LOW	IS THERMOSTAT SETTING INCORRECT?	Y	ADJUST TO PROPER SETTING.
	N		
	IS THERMOSTAT FAILING TO OPERATE?	Y	CHECK THERMOSTAT, REPAIR OR REPLACE AS NECESSARY.
	N		
	IS SOLENOID VALVE FAILING TO OPERATE PROPERLY?	Y	CHECK SOLENOID VALVE SWITCH AND COIL, REPAIR OR REPLACE PARTS OR VALVE AS NECESSARY.
	N		
	IS THE ELECTRICAL CIRCUIT FAILING TO OPERATE PROPERLY?	Y	CHECK ELECTRICAL CIRCUIT AND FUSES, REPAIR OR REPLACE PARTS AS NECESSARY.
	N		


COMPARTMENT TEMPERATURE TOO LOW (Cont.)
IS HAND EXPANSION VALVE LEAKING?
Y
CHECK POSITION OF VALVE FOR TIGHT CLOSING. CHECK FOR DIRT OR CORROSION AT SEAT AND PIN. CLEAN, REPAIR, OR REPLACE.
LIQUID REFRIGERANT CYCLING THROUGH THE COOLING COIL WITH WIDE VARIATION IN SUPERHEAT AT THERMAL ELEMENT LOCATION.
IS EXCESSIVE OIL CIRCULATING THROUGH SYSTEM?
Y
CHECK OTHER SYMPTOMS FOR A LIKE CONDITION. (SEE OIL LEAVES CRANKCASE AND OIL DOES NOT RETURN TO CRANKCASE.)
N
IS MOISTURE OR ICE AT THERMAL ELEMENT CONTACT WITH SUCTION LINE AFFECTING TRUE OPERATION?
Y
REMOVE, DRY, AND PROPERLY INSULATE.
N
IS EXPANSION VALVE DEFECTIVE?
Y
CHECK THERMAL ELEMENT FOR RESPONSE. REPAIR OR REPLACE.
N
IS THERMAL ELEMENT LOCATED IN SUCH A POSITION AS TO BE AFFECTED BY AIRFLOW?
Y
REMOVE AND RELOCATE AND INSULATE.
N
ARE EXPANSION VALVES TOO LARGE OR HAVE IMPROPER THERMOSTATIC CHARGE?
Y
SEE TECHNICAL MANUAL FURNISHED WITH EQUIPMENT FOR SELECTED SIZE AND TYPE. INSTALL PROPER VALVES.
N

LIQUID REFRIGERANT CYCLING THROUGH THE COOLING COIL WITH WIDE VARIATION IN SUPERHEAT AT THERMAL ELEMENT LOCATION. (Cont.)	IS THERE MOISTURE IN EXPANSION VALVE PORT OR WORKING PARTS?	Y	TO CHECK, HEAT VALVE BODY SLOWLY, TAKING CARE NOT TO DAMAGE POWER ELEMENT AND GASKETS. HEAT WILL TEMPORARILY FREE VALVE PARTS AND RESUME AUTOMATIC OPERATION. IF MOISTURE IS PRESENT, DISASSEMBLE VALVE, CLEAN AND REPLACE. CHECK MOISTURE INDICATOR AND REPLACE DEHYDRATOR CARTRIDGE IF NECESSARY.
LIQUID REFRIGERANT CARRYING THROUGH THE COIL AND FAR BEYOND THE THERMAL ELEMENT LOCATION WITH LITTLE SUPERHEAT AT THIS POINT.	IS EXPANSION VALVE OPEN TOO WIDE?	Y	ADJUST TO CLOSE.
	N		
	IS THERMAL ELEMENT MAKING POOR CONTACT WITH SUCTION PIPING?	Y	REMOVE, CLEAN BOTH SURFACES, AND INSULATE.
	N		
	IS THERMAL ELEMENT IMPROPERLY LOCATED OR INSULATED?	Y	REMOVE, LOCATE PROPERLY, AND INSULATE.
	N		
	IS EXPANSION VALVE LEAKING?	Y	CHECK WHEN COMPRESSOR SHUTS DOWN BY LISTENING AT VALVE FOR A HISSING SOUND. CHECK FOR DIRT OR CORROSION OF SEAT. CLEAN, REPAIR, OR REPLACE.
LIQUID REFRIGERANT CARRYING PARTIALLY THROUGH THE COIL WITH CONSIDERABLE SUPERHEAT AT THERMAL ELEMENT LOCATION.	IS THERE MOISTURE IN EXPANSION VALVE PORT OR WORKING PARTS?	Y	SEE SAME CONDITION AND CORRECTION AS ABOVE.
	N		
	IS LIQUID LINE STRAINER CLOGGED OR DIRTY?	Y	REMOVE, CLEAN, AND REPLACE.
	N		
	IS EXPANSION VALVE IMPROPERLY ADJUSTED?	Y	CHECK SUPERHEAT AND ADJUST.
	N		



LIQUID REFRIGERANT CARRYING PARTIALLY THROUGH THE COIL WITH CONSIDERABLE SUPERHEAT AT THERMAL ELEMENT LOCATION. (Cont.)

IS THERE A SHORTAGE OF REFRIGERANT?

Y — CHECK SHORTAGE, TEST FOR LEAKS AND CHARGE.

N

IS EXPANSION VALVE THERMAL ELEMENT IMPROPERLY LOCATED?

Y — CHECK AND RELOCATE.

N

IS EXPANSION VALVE TOO SMALL?

Y — SEE TECHNICAL MANUAL FURNISHED WITH EQUIPMENT, AND INSTALL PROPER SIZE AND TYPE.

N

IS REFRIGERANT GAS IN LIQUID LINE?

Y — CHECK FOR EXCESSIVE PRESSURE LOSS IN LIQUID LINE. OPEN VALVES OR RESTRICTIONS AFFECTING LOSS.

N

IS PRESSURE DROP THROUGH COOLING COILS EXCESSIVE?

Y — CHECK FOR RESTRICTIONS, OIL TRAPS OR VALVES PARTIALLY CLOSED. DRAIN OIL OR OPEN RESTRICTIONS AS APPLICABLE.

N

HAS EXPANSION VALVE POWER ELEMENT LOST CHARGE OF REFRIGERANT?

Y — REMOVE THERMAL ELEMENT AND HEAT BY HAND TEMPERATURE. IF NOT RESPONSIVE, REPLACE POWER ASSEMBLY OR VALVE.

N

IS EXPANSION VALVE EQUALIZER LINE CLOSED OR RESTRICTED?

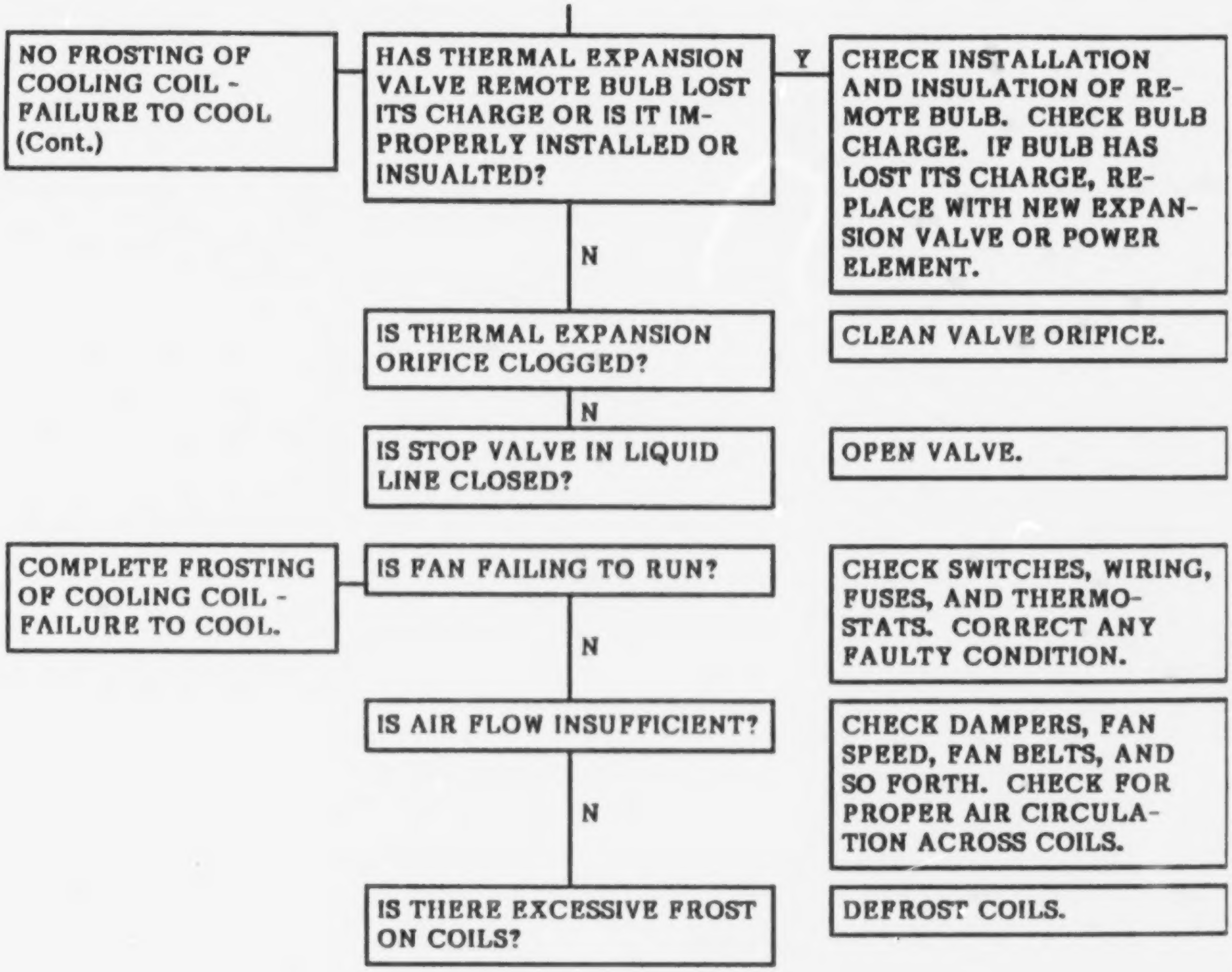
Y — CHECK AND OPEN OR REPLACE.

N

IS EXPANSION VALVE THERMAL ELEMENT BEING AFFECTED BY REFRIGERANT FROM ANOTHER COOLING COIL CIRCUIT?

Y — CHECK LOCATION OF THERMAL ELEMENT. REMOVE AND PROPERLY LOCATE.

PARTIAL FROSTING OF COOLING COIL - FAILURE TO COOL	IS THERE INSUFFICIENT REFRIGERANT IN SYSTEM?	Y	ADD REFRIGERANT AS REQUIRED.
	N		
	IS LIQUID LINE RESTRICTED OR IS LIQUID LINE STRAINER SCREEN CLOGGED?	Y	PUMP DOWN AND CLEAN OUT LINE OR STRAINER SCREEN.
	N		
	IS SUCTION PRESSURE REGULATOR SET TOO HIGH?	Y	RESET REGULATOR TO MAINTAIN REFRIGERANT IN COILS AT APPROXIMATELY 15 °F LESS THAN COMPARTMENT TEMPERATURE.
	N		
	IS SOLENOID VALVE PARTIALLY CLOGGED?	Y	PUMP DOWN AND CLEAN SOLENOID.
	N		
	IS THERMAL EXPANSION VALVE IMPROPERLY SET?	Y	RESET EXPANSION VALVE TO 8 °F TO 10 °F SUPERHEAT.
NO FROSTING OF COOLING COIL - FAILURE TO COOL	IS SOLENOID VALVE CLOGGED?	Y	PUMP DOWN AND CLEAN SOLENOID.
	N		
	IS SOLENOID COIL BURNED OUT?	Y	CHECK TO SEE IF COIL RESPONDS TO CURRENT. IF NOT, REPLACE COIL.
	N		
	IS SOLENOID THERMOSTAT SET TOO HIGH?	Y	RESET THERMOSTAT TO MAINTAIN DESIRED TEMPERATURE.
	N		
	IS COMPRESSOR FAILING TO RUN?	Y	DETERMINE CAUSE OF COMPERSSOR SHUTDOWN. MAKE ANY ADJUSTMENTS REQUIRED AND RESTART.
	N		
	IS THERMAL EXPANSION VALVE IMPROPERLY SET?	Y	RESET EXPANSION VALVE TO 8 °F TO 10 °F SUPERHEAT.
	N		



NO FROSTING OF COOLING COIL - FAILURE TO COOL (Cont.)	HAS THERMAL EXPANSION VALVE REMOTE BULB LOST ITS CHARGE OR IS IT IMPROPERLY INSTALLED OR INSUALTED?	CHECK INSTALLATION AND INSULATION OF REMOTE BULB. CHECK BULB CHARGE. IF BULB HAS LOST ITS CHARGE, REPLACE WITH NEW EXPANSION VALVE OR POWER ELEMENT.
	IS THERMAL EXPANSION ORIFICE CLOGGED?	CLEAN VALVE ORIFICE.
	IS STOP VALVE IN LIQUID LINE CLOSED?	OPEN VALVE.
COMPLETE FROSTING OF COOLING COIL - FAILURE TO COOL.	IS FAN FAILING TO RUN?	CHECK SWITCHES, WIRING, FUSES, AND THERMOSTATS. CORRECT ANY FAULTY CONDITION.
	IS AIR FLOW INSUFFICIENT?	CHECK DAMPERS, FAN SPEED, FAN BELTS, AND SO FORTH. CHECK FOR PROPER AIR CIRCULATION ACROSS COILS.
	IS THERE EXCESSIVE FROST ON COILS?	DEFROST COILS.

*CONTINUOUS COMPRESSOR OPERATION IS NORMAL IN FULL LOAD AIR-CONDITIONING APPLICATIONS.

Reference

Refrigeration Systems. U.S. Navy Manual, S9086-RW-STM-010/CH-516.

Competency:

1. Demonstrate basic safe practices associated with rigging.

Instructional Objectives:

1. Identify types and uses of wire rope and slings.
2. Install wire rope clips properly.
3. Inspect rope, chains, hooks, shackles, and eye bolts for wear.
4. Identify hand signals for lifting and moving loads.
5. Use hand signals for lifting and moving loads.
6. Demonstrate the use of portable hand hoisting equipment.
7. Identify safety precautions necessary when working with rigging equipment.
8. Tie knots and make hitches with fiber rope.
9. Calculate the safe working loads for rigging devices.
10. Demonstrate the proper procedure for rigging pipe and valves.

Learning Activities:

1. Read pages 10-13, 18-23, 45-68, 77-84, 94-95, 98-99, 104-111, in Handbook for Riggers. Be familiar with the charts and know the Rules of Thumb.
2. Examine the rigging equipment on display in your classroom.
3. Observe as your instructor demonstrates how to tie a square knot, a figure eight knot, a bowline knot, and makes a sheet bend, a half hitch, a blackwell hitch, a cat's paw hitch, a rolling hitch and a timber hitch with fiber rope.
4. View the videotapes "Basic Rigging - 1" and "Basic Rigging - 2." (NUS Training Corporation).
5. Give a presentation on a topic assigned by your instructor. Include a visual aid or demonstration.
6. Complete the Rigging Fundamentals Worksheet.

Application Exercises:

1. Install wire rope clips properly.
2. Demonstrate the use of hand signals for lifting and moving loads.
3. Demonstrate the use of portable hand hoisting equipment.
4. Demonstrate the proper procedure for rigging pipe and valves.
5. Tie knots and make hitches with fiber rope.

Evaluation/Checkout:

1. Submit Rigging Fundamentals Worksheet.
2. Submit your checklist of application exercises.
3. Give a presentation on a topic assigned by your instructor. Include a visual aid or a demonstration.
4. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Examples of wire rope, chains, hooks, shackles, and eyebolts for classroom display. Both new and worn examples should be presented.
2. Fiber rope to demonstrate knots, bends, and hitches.
3. The application exercises should be completed on-the-job. A list of the application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure.

Learning Materials:

1. Newberry, W. G., Handbook for Riggers. Calgary, Alberta: Newberry Investments Company, Ltd., 1977. Newberry Investments Company, Ltd., P.O. Box 2999, Calgary, Alberta Canada, T2P 2M7 (403) 281-1957.
2. For the presentation, the apprentice could: (1) demonstrate how to tie knots, bends, and hitches with fiber rope; (2) bring in examples of rigging equipment used in his/her plant; or (3) demonstrate how to properly rig pipe.
3. A copy of the worksheet and answers and test and answers is included with this unit.

Audio-Visual Material:

1. The videotapes "Basic Rigging - 1" and "Basic Rigging - 2" are available from NUS Training Corporation. Basic Rigging - 1 overviews the fundamentals of a rigging job: basic principles; ropes, chains, and slings; hooks, shackles, turnbuckles, eyebolts, and load levelers; and chain hosts and come-alongs.

   Basic Rigging - 2 expands on the concepts and skills introduced in the preceding unit. All pertinent steps in a rigging job are discussed: planning a job (weight, balance, clearances, equipment selection); equipment preparation (connectors, slings, hoists); rigging the job (mounting connectors, slings, hoists); taking up slack; and moving the load (safety, hand signals, lifting, and traveling). By the end of the unit, trainees will be able to assist an experienced rigger with an actual rigging job.

   A workbook is supplied with each unit.

Resources:

1. Books:
   - A. Rossnagel, W. Handbook of Rigging. New York: McGraw-Hill, 1964. Maintenance, 1974.
   - B. Rigging: Wire Rope Slings. Trenton, New Jersey: Marshall Maintenance, 1974.
   - C. Rigging Equipment Over the Floor. Trenton, New Jersey: Marshall Maintenance, 1984.
   - D. NAPHCC Safety Manual. Falls Church, Virginia: National Association of Plumbing, Heating, and Cooling Contractors, P.O. Box 6808, Falls Church, VA 22046.

E. Riggers Handbook. Sedalia, Missouri: Broderick and Bascom Rope Company, 1988. (Route 3, Oak Grove Industrial Park, P.O. Box 844, Sedalia, MO 65301)
F. Wire Rope Handbook. Sedalia, Missouri: Broderick and Bascom Rope Company, 1983.
G. Rigging. Barrington, Illinois: TPC Training Systems, 1975. (1301 S. Grove Avenue, Barrington, IL 60010)
H. Steelworker 3 & 2, (NAVEDTRA 10653-F1). Washington, D.C.: Naval Education and Training Program Development Center, 1983, Chapters 14, 15, and 16. Available from the U.S. Government Printing Office, Stock Ordering No. 0502-LP-053-2665.
I. Rigging Manual. Toronto, Ontario: Construction Safety Association of Ontario, 1982. (74 Victoria Street, Toronto, Ontario Canada M5C 2A5)

2. Audio-Visual Materials:
   A. "Rigging With Wire Rope Slings" is a videotape available from Marshall Maintenance Productions.
   B. "Rigging Over the Floor" is a videotape available from Marshall Maintenance Productions.
   C. "Rigging and Lifting" is a videotape and workbook available from Industrial Training Corporation.
   D. "Chain Care, Use, and Inspection" is a videotape available from Columbus McKinnon Corporation, Marketing Communications, Audubon and Sylvan Parkways, Amherst, NY 19228.
   E. "Hoist Safety" is a videotape available from Columbus McKinnon Corporation.
   F. "Safety in Rigging Series" is a series of ten videotapes. The first three tapes focus on crane operations and the remaining tapes highlight specifications and uses for particular rigging components such as slings and hardware. Instructor's notes are included with each tape. The series is available from Construction Safety Association of Ontario, 74 Victoria Street, Toronto, Ontario Canada M5C 2A5.
   G. "Advanced Rigging - 1" and "Advanced Rigging - 2" are videotapes available from NUS Training Corporation.
   H. "Basic Rigging: Trolleys and Hoists" is a videotape available from DuPont Training Materials, DuPont Company, Wilmington, Delaware, 19898. A training manual on basic rigging is also available.

3. Seminars:

A.	Jim Zajac	CM-Hoist	(716) 689-5600
B.	Lee Kraus	Wisco-Lift	(414) 731-4401
C.	Tim Lock	Leschen-Rope	(312) 543-3133
D.	Bob Molitor	Up-Riggers	(414) 739-7587

Rigging Fundamentals Worksheet

1. Name two types of hoists with respect to lifting medium.

2. In rigging three types of rope are used. List them and explain why they are used.

3. Which is stronger 3 or 4 strand rope? Why?

4. True or False - Manila rope should be lubricated with raw linseed oil.

5. What is the safety factor of splicer in rope?

6. Why should wire rope be lubricated?

7. What is considered a safe load factor for wire rope? Hemp rope?

8. Explain rope classification 6x19 and 6x37.

9. Name five common causes of wire rope failure.

10. What is the proper way of attaching wire rope clips?

11. Why are wire rope slings considered the safest type?

12. How is wire rope measured?

13. How can the weight of an object be determined?

14. At what particular point is a link of chain likely to fail?

15. What is the weakest point of a wire rope sling?

16. What happens to wire rope as it is bent?

17. How may a permanently kinked sling be repaired?

18. In what ways may wire rope lose its strength?

19. How can the sharp corners of a load be eliminated?

20. Explain the term "safety factor" as it pertains to rope slings under ordinary conditions of use.

21. How does the "angle of loading" affect the capacity of a bridle sling?

22. What do the abbreviations F.C. and I.W.R.C. mean?

23. How much weight would be lifted if you had thirty 30' lengths of 2" STD pipe? (Use chart on page 117 in text)

24. How much weight would be lifted if you had three 15' lengths of 6" Sch 40 pipe?

Rigging Fundamentals Worksheet Answers

1. Rope and chain

2. Cotton-light duty, much handling, easy on hands
   Manila-hoisting, block and tackle
   Wire-heavy duty applications

3. 4 strand, stronger and more pliable. The fourth strand (around the central core) gives rope inherent stability and thus added strength.

4. False

5. Splices weaken rope. Eyesplice-90%, Shortsplice-80%

6. Reduce friction and prevent corrosion.

7. 3-8, 3-10

8. 6 strands, 19 wires/strand
   6 strands, 37 wires/strand

9. Crushing, birdcaging, locking, fatigue, pitting.

10. U-bolt should bear on short (dead) end of rope. Clip (saddle) should bear on long (running) end not less than 6" apart.

11. Except for special application-strongest and most flexible.

12. Over the full diameter.

13. Check papers, charts, weight plate, catalogs, calculate the volume of the object times weight of one cubic foot of particular material.

14. At the wear point between two links.

15. The hook is weakest.

16. Inside is compressed and outside is stretched.

17. Don't repair-replace.

18. Splices, kinks, corrosion, angle of hitch, turns in rope.

19. Pad corners with iron.

20. Breaking load/safe load = safety factor

21. The closer the angle is to the vertical (90 degrees) the stronger the sling. The closer the angle is to the horizontal, the weaker the sling.

22. FC-fiber core, IWRC-independent wire rope core

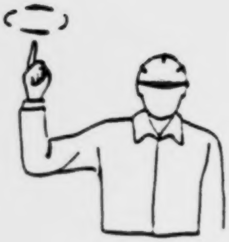
23. 3285 lbs.

24. 853.65 lbs.

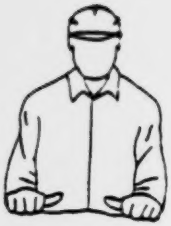
Rigging Test

1. Identify the following hand signals.

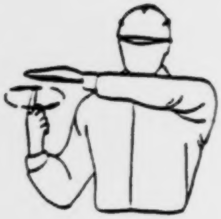
a. ____________________



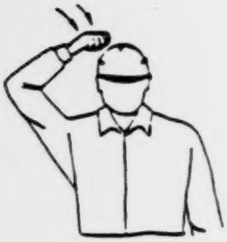
b. ____________________



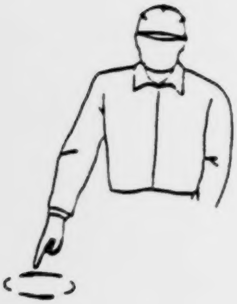
c. ____________________



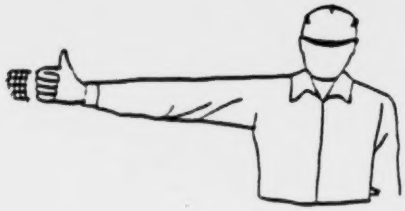
d. ____________________



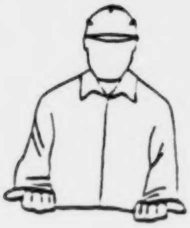
e. ____________________



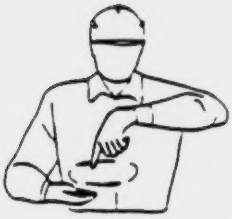
f. ______________________________



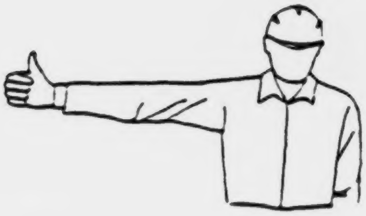
g. ______________________________



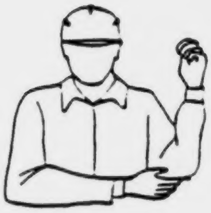
h. ______________________________



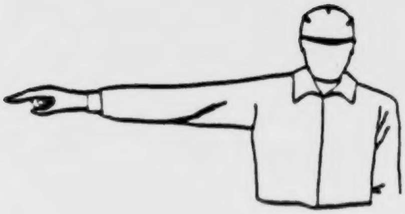
i. ______________________________



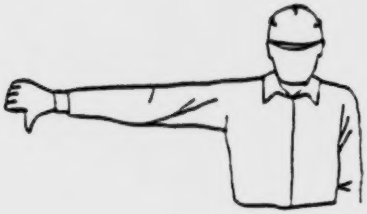
j. ______________________________



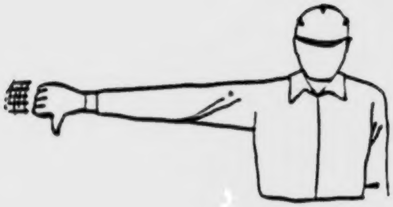
k. ____________________________



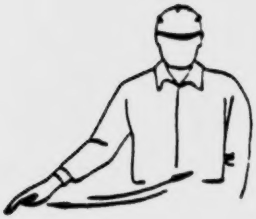
l. ____________________________



m. ____________________________



n. ____________________________



2. _____ Which of the following is not considered a safety procedure for rigging operations?

   a. be sure the sling angle on a load is always less than 45 degrees
   b. avoid dragging rope slings from beneath loads
   c. avoid bending the wire rope near any attached fitting
   d. be sure that the wire rope has been wrapped completely around a hook to avoid slippage

3. _____ To prevent a load from tipping when you lift it, attach the hoist on the load:

    a. at one end
    b. below its center of gravity
    c. at or above its center of gravity
    d. in the middle

4. _____ Compared to manila slings, synthetic slings are:

    a. stronger
    b. larger
    c. more likely to deteriorate
    d. more likely to slip

5. _____ The ______________ sling produces 360 degrees contact with the load and tightens as the lift takes place.

    a. double choker hitch
    b. double wrap basket hitch
    c. single choker hitch
    d. bridle hitch

6. _____ The capacity of any sling depends upon its ______________.

    a. size
    b. shape
    c. the angles formed by the sling legs and the vertical
    d. all of the above

7. _____ What is a good type of sling to use on a load requiring good gripping action, such as a load of pipe?

    a. basket sling
    b. choker sling
    c. bridle sling
    d. grommet sling

8. _____ What should you look for when inspecting fiber rope slings?

    a. deterioration due to exposure
    b. broken or cut fibers
    c. proper splicing
    d. all of the above

9. _____ Which of the following is true with regard to safe use of shackles:

   a. shackle pins should never be replaced with a bolt
   b. all screw pins should be completely seated
   c. cotter pins should be used with all round pin shackles
   d. all of the above

10. _____ What must you know about a rope to prevent overloading?

   a. its breaking strength
   b. the safety factor
   c. its safe working load
   d. all of the above

11. _____ The safety factor is the ratio between the rope's breaking strength and:

   a. length
   b. circumference
   c. safe working load
   d. the number of yarns

12. _____ When using cable or crosby clips to make an eye, the first clip should be placed _______________________.

   a. one width of the clip from the start of the loop
   b. as near the loop as possible
   c. as near the center of the turned back rope as possible
   d. one width of the clip from the dead end of the rope

13. _____ You need to estimate the location of an object's center of gravity to determine :

   a. its weight
   b. its volume
   c. where to attach a hoist
   d. its mechanical advantage

14. _____ When using a pair of choker slings, arrange the hooks so they:

   a. pull from opposite sides
   b. pull from the same side
   c. are both at the center of gravity
   d. pull from the bottom of the load

15. _____ If you are not sure that a hook is strong enough to lift the load:

a. use two hooks
b. use wire rope
c. use a choker sling
d. use a shackle

16. _____ A temporary fastening of rope to a ring, pole, or hook is called a:

a. knot
b. bend
c. reef
d. hitch

17. _____ To keep wire rope slings pliable and prevent rust, you should:

a. keep them warm
b. lubricate them
c. inspect them
d. use them only in high temperature areas

18. _____ Which of the following will decrease the breaking strength of a fiber rope?

a. kinks
b. knots
c. sharp bends
d. all of the above

19. _____ To temporarily interweave two heavy ropes, hawsers, or cables, use a:

a. granny knot
b. thief knot
c. carrick bend
d. half hitch

20. _____ If a sling with two legs is used to lift a one ton object, the object will produce a half-ton load on each leg if the lift angle is ________________________.

a. 90 degrees
b. 45 degrees
c. 60 degrees
d. 30 degrees

21. _____ If you install a U-bolt clip properly, it will provide what percentage of rope strength?

a. 20%
b. 40%
c. 80%
d. 100%

22. _____ One of the most common of all wire rope failures is due to:

- a. rust
- b. dirt
- c. lubrication
- d. kinking

23. _____ The best grade of wire material for wire rope is:

- a. traction steel
- b. iron wire
- c. mild plow steel
- d. improved plow steel

24. _____ A 6 x 19 wire rope has 6 strands and 19:

- a. wires
- b. wires per strand
- c. wires in the core
- d. inches circumference

25. _____ Which of the following are advantages of chain over wire rope?

- a. more resistance to corrosion
- b. better stretching ability
- c. greater resistance to sudden shocks
- d. all of the above

True or False

26. _____ The only protective clothing required is a hard hat and safety shoes.

27. _____ The safe working load, or load rating, for a piece of equipment is usually marked on the equipment.

28. _____ Only chains marked 40 or 60 should be used for overhead lifting.

29. _____ An elongated lay of wire rope indicates that the rope has been overloaded or that the core has failed.

30. _____ Shackles are used on slings that have the bolt section located over the hook and slings eyes placed in the bowl of the shackle.

31. _____ When applying wire rope clips, the U-bolt should bear against the dead, or short, end of the rope.

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32. _____ If a hook has been overloaded or if it is beginning to weaken, the throat will open.

33. _____ The double choker hitch is suited to lifting loose bundles of pipe.

34. _____ It is important to rig the load so that the center of gravity is directly below the hook.

35. _____ For the purposes of safety, there should always be two people signaling for each lift.

36. _____ Do not use carbon steel chokers on stainless steel pipe or valves.

37. _____ Never rig a valve around the handwheel or through the valve.

38. _____ Sling angles over 45 degrees should be considered dangerous.

39. _____ As the sling angle decreases, the amount of load on each leg increases.

40. What is the safe working load of a 3/4" polyester rope?

41. What is the safe working load of a 1/2" nylon rope?

42. What is the safe working load of 1/2" diameter chain stock?

43. What is the safe working load of a 1/2" wire rope?

44. What is the safe working load of a 3/4" wire rope?

45. How much weight would be lifted if you had ten 15' lengths of 10" STD pipe? (Use chart on page 117 in text)

46. How much weight would be lifted if you had seven 10' lengths of 4" Sch 80 pipe?

Rigging Test Answers

1. a. Raise load
   b. Retract boom
   c. Raise load slowly
   d. Use load line
   e. Lower load
   f. Raise boom and lower load
   g. Extend boom
   h. Lower load slowly
   i. Raise boom
   j. Use whip line
   k. Swing
   l. Lower boom
   m. Lower boom and raise load
   n. Stop

2. d
3. c
4. a
5. b
6. d
7. b
8. d
9. d
10. d
11. c
12. d
13. c
14. a
15. d
16. d
17. b
18. d
19. c
20. a
21. c
22. d
23. d
24. b
25. a
26. F
27. T
28. T
29. T
30. T
31. T
32. T
33. T
34. T
35. F
36. T
37. T
38. T
39. F
40. 2,160 lbs.
41. 960 lbs.
42. 3,000 lbs.
43. 2,000 lbs.
44. 5,000 lbs.
45. 6,072 lbs.
46. 1,048.6 lbs.

Competency:
1. Design templets and develop patterns into models.

Instructional Objectives:
1. Layout a cylindrical sleeve.
2. Layout a semicircular tank.
3. Layout a circular sleeve and flange.
4. Describe the design and layout of welded joints.
5. Describe patterns and templets.
6. Develop a templet for a 90 degree, two-piece turn.
7. Develop a templet for a two-piece turn of 32 degrees.
8. Develop a templet for a 90 degree, three-piece turn.
9. Develop a templet for a 90 degree, four-piece turn.
10. Develop a templet for a branch and header of equal diameters.
11. Develop a templet for a branch and header of unequal diameters.
12. Develop a templet for an eccentric branch and header.
13. Develop a templet for a lateral connection of equal diameters.
14. Develop a templet for a lateral connection with unequal diameters.
15. Develop a templet for a 60 degree, true wye.
16. Develop a templet for a blunt head.
17. Develop a templet for an orange peel head.
18. Develop a templet for a concentric reducer.
19. Develop a templet for an eccentric reducer.
20. Develop a templet for a welded combination offset.
21. Develop a templet for a rolling offset.

Learning Activities:
1. Read Units 2, 4-21 in Templet Development for the Pipe Trades.
2. Complete the Review Questions at the end of Units 2, 4-21 in Templet Development for the Pipe Trades.
3. Complete Assignments 2, 4, 6-21 in Templet Development for the Pipe Trades.

Evaluation/Checkout:
1. Submit your answers to the Review Questions from Units 2, 4-21.
2. Submit your completed Assignments from Units 2, 4, 6-21.

Learning Materials:
1. Jones, R., Templet Development for the Pipe Trades. Albany, New York: Delmar Publisher, 1966.
2. The review questions and assignments are in the text.

Resources:
1. Books
    A. Frankland, T. Pipe Templet Layout. Mission Hills, California: Glencoe Publishing Company, 1967.

Competency:

1. Fabricate pipe intersections through the use of templets.

Instructional Objectives:

1. Fabricate reducers, tees, reduced tees, 90's, and laterals using templets.

Learning Activities:

1. Using the templets developed in Templet Development I, fabricate the following:
   - 90 degree, three-piece turn.
   - 32 degree, two-piece turn.
   - 90 degree, four-piece turn.
   - branch and header, equal diameters.
   - branch and header, unequal diameters.
   - lateral connection, equal diameters.
   - lateral connection, unequal diameters.
   - concentric reducer.
   - eccentric reducer.

Evaluation/Checkout:

1. Submit the pipe fabrications for evaluation.

Learning Material:

1. The templets developed in Templet Development I should be used to do the fabrications. The skill and background of the apprentice will determine how far he/she progresses in the fabrication process The apprentice should be able to: (1) layout the templet; (2) cut the pipe; (3) bevel the pipe; and (4) align the pipe. Whether they will be able to (5) tack weld and (6) weld the joint will be influenced by their degree of welding skill.

Competency:
1. Identify piping system valve types and applications.
2. Describe and use different types of packings and gasket materials by appropriate application.
3. Demonstrate the ability to repair/install valves.

Instructional Objectives:
1. Explain the function of valves.
2. Describe the various types of valves.
3. Define terms and abbreviations related to valves.
4. State the common types of materials from which valves are constructed.
5. Identify the various end connections available for valves.
6. Describe the purpose of valve packing.
7. Summarize common reasons for valve failure and recommend repair procedures.
8. Outline the procedures for maintaining and installing valves.
9. Repack a valve.
10. Install valves with threaded ends, butt-welded and socket-welded ends, and flanged ends.
11. Identify the different types of material gaskets are made of.
12. Match gasket composition to its appropriate application.
13. Disassemble, repair, and reassemble a gate valve.

Learning Activities:
1. Read "Piping Pointers" from Crane Company.
2. Read "Choosing the Right Valve" from Crane Company.
3. Read Chapter 5 in Pipe Fitting and Piping Handbook.
4. Read the Packing Information Sheet.
5. Examine valves and/or valve cutaway models on display in your classroom.
6. Complete the Valves Worksheet.
7. View the videotapes "Valve Maintenance 1 and 2" (NUS Training Corporation).

Application Exercises:
1. Repack a valve.
2. Install a valve with a threaded end.
3. Install a valve with a butt welded end.
4. Install a valve with a socket welded end.
5. Install a valve with a flanged end.
6. Disassemble, repair, and reassemble a gate valve.

Evaluation/Checkout:
1. Submit Valves Worksheet
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Equipment:

1. Samples of several types of valves or valve cutaways for classroom display.
2. The application exercises should be completed on-the-job. A list of application exercises is provided in the Industrial Pipefitter Competency Profile. The instructor should make sure the apprentice is familiar with the procedure and with the tools necessary to accomplish the task.

Learning Materials:

1. "Piping Pointers" and "Choosing the Right Valve" are available from Crane Company. Contact: Crane Company, Valve Division, 800 Third Ave., King of Prussia, PA 19406, Attn: Kim Weber, (215)265-5050.
2. Lamit, L. Pipe Fitting and Piping Handbook. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.
3. A copy of the worksheet and answers, the information sheet, and the test and answers is included with this unit.

Audio-Visual Materials:

1. The videotapes "Valve Maintenance 1" and "Valve Maintenance 2" are available from NUS Training Corporation. In "Valve Maintenance 1" the full range of valves and their components are described-gate valves, ball valves, butterfly valves, diaphragm valves, and check valves. The function and use of each type of valve is also explained to prepare trainees to disassemble, identify components, and reassemble various valves used in the plant. In "Valve Maintenance 2" the basics of valve maintenance are presented including inspection for damage, identifying various maintenance problems and malfunctions, and overhaul techniques. Among the topics are adjusting old valve packing, adjusting new valve packing, packing valves, repairing damaged valves, and typical maintenance practices (inspection, job preparation, disassembly, and reassembly). A worksheet is included with each unit.

Resources:

1. Books
    - A. Mead, J. Valve Selection and Service Guide. Troy, Michigan: Business News Publishing Company, 1986.
    - B. Waring, R. Handbook of Valves, Piping, and Pipelines. Brookfield, Vermont: Brookfield Publishing Company, 1983.
    - C. Designing with Seals and Gaskets. Cleveland, Ohio: Penton Education Division, 1985.
    - D. Zappe, R. Valve Selection Handbook, 2nd edition. Houston, Texas: Gulf Publishing Company, 1987.
    - E. Hull Maintenance Technician 3 & 2, Volume 1 (Naval Education and Training Command, NAVEDTRA 10571). Washington, D.C.: United States Government Printing Office, 1984. (Stock Ordering No. 0502-LP-052-8630).
    - F. Manufacturers Standardization Society of the Valve and Fittings Industry, Inc. publishes numerous books and pamphlets. For a list contact: Olen Thronton, Executive Director, MSS, 127 Park Street, N.E., Vienna, VA 22180, (703)281-6613.

2. Pamphlets:
   A. Descriptive literature of the valves Watts Regulator Company produces is available from: Rich Davison, Jr., Watts Regulator, c/o Advance Industrial Marketing Limited, P.O. Box 87, 923 S. Bird St., Sun Prairie, WI 53590, (608)837-5005. A condensed catalog is available. Order CBV-845 and C-85B.
   B. Crane Company produces an extensive index of their valves including engineering data. The address is given above.
   C. "Handbook of Valve Information - Powell Valves" (Form 321) is available from The Wm. Powell Company, 2503-31 Spring Grove Avenue, P.O. Box 14006, Cincinnati, OH 45214, (513)852-2000.
   D. Grinnell Supply Sales Company has descriptive literature available on the valves they manufacture. Contact: Grinnell, Marketing/Design Services, 1341 Elmwood Ave., Cranston, RI 02910, (401)941-8000.

3. Audio-Visual Material:
   A. "Safety Valves 1 and 2", "Gaskets, Packing, and Mechanical Seals", "Valves -1: Valve Types and Functions", "Valves -2: Valve Operations" are videotapes available from NUS Training Corporation.
   B. "Piping and Valve Maintenance" is a series of videotapes available from Industrial Training Corporation.
   C. "Seals, O-Rings, and Gaskets" is a videotape available from Industrial Training, Inc.
   D. "Valves" is a videotape available from Tel-A-Train.
   E. "Choosing the Right Valve" is a videotape available from Crane Company. The address is given above.

Packing Information Sheet

Packings are used to prevent leakage around the stem of a valve. The packing fits around the stem and is compressed between the packing gland and the bonnet of the valve.

What type of packing to employ depends upon what use the valve will receive, in addition to the limitations of the valve and packing themselves. Service factors to consider include pressure, temperature, and pH reactions.

Traditionally, packing materials have included asbestos in some form. However, due to the increasing restrictions on its use, other materials have been developed. A description of some of these materials follows:

Grafoil -- This is an all graphite packing with a temperature limit of 1000 degrees F in an oxidizing atmosphere and 6000 degrees F in a nonoxidizing atmosphere. Its pH range is 0 through 14 except in strong oxidizing acids.

Graphite Filament Yarn -- This is a braided material that can handle temperatures to 1000 degrees F in an oxidizing atmosphere and go somewhat higher in a nonoxidizing atmosphere. Its pH range is from 0 to 14 and it is basically a carbonized rayon.

Kevlar -- This material is an aramid fiber with a very high tensile strength and a pH range of 3 to 11. It is good up to 500 degrees F. Because of its very high tensile strength, it can withstand high pressures and can be used where stem support is required.

TFE Filaments -- TFE filaments can be furnished dry or impregnated with either TFE dispersion or a silicon lube. They have a temperature range to 500 degrees F and a pH range from 0 through 14. TFE packings are used in all types of chemical applications (Mead, 1986).

In addition to asbestos, flax has been used for years. Its temperature range is under 150 degrees F and has a pH range of 6-8. However, flax packings can handle high pressures.

Metallic packings have also been in use for many years. A description of some of these follows:

Babbitt -- This is a lead-based material that can withstand temperatures up to 500 degrees F and has a pH range of 3 to 10. Babbitt has been used up to 5000 psig in valves.

Aluminum -- Aluminum has a temperature range up to 1000 degrees F and a pH range of 2 through 11. It is being used in valves handling heat transfer fluids as well as some selected acids.

Copper -- Copper is another material that has a temperature range of up to 1000 degrees F and a pH range of 2 through 11. It is used primarily in hot water, steam, and hot oil valves (Mead, 1986).

Asbestos packings are still available as braided asbestos or wire-inserted asbestos. Some can be used in temperatures up to 1200 degrees F and they can have a pH range of 3 to 10. Plain asbestos packings have temperature ranges below 500 degrees F and a pH range of 4 to 8. These are normally used in low temperature, low pressure valves. Asbestos packing may be TFE coated to increase its temperature and pH ranges and is popular in many steam and water applications.

Where fluids carry abrasives, suspended solids, precipitating, evaporating, and congealing liquids, the lantern ring is sometimes used. This separates two sets of packings and provides a means of introducing flushing material under pressure, such as a grease, that keeps the packings lubricated and flushes out foreign material (Mead, 1986).

Reference:

Mead, J. Valve Selection and Service Guide. Troy, Michigan: Business News Publishing Company, 1986.

Valves Worksheet

1. List the five principle functions of valves.

2. List three types of valves that should be used only for off/on service.

3. List three types of valves used to prevent back flow.

4. List two types of valves that operate by turning the handle 90 degrees.

5. What are the three basic materials valve bodies are made from?

6. Where is the valve identification information located on a valve?

7. What information is usually cast into the valve body?

8. Where is the NRS type valve useful?

9. What does discoloration or residue on the bonnet of a valve indicate?

10. Where does the most wear occur in a gate valve?

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11. What is a good temporary repair for valves?

12. What safety precaution should be taken when working on boiler lines?

13. Where are renewable disc globe valves generally used?

14. Why are most globe valves installed with pressure under the seat?

15. What precautions must be observed when installing ball valves?

16. What type of service are butterfly valves especially suited for?

17. List the two basic types of butterfly valves.

18. List four steps required in proper installation of a valve with threaded joints.

19. Why is it best to install valves with the bonnet up whenever possible.

20. Why must all water be drained from existing lines before attempting to make a solder joint?

21. What is the purpose of the flux in a soldered fitting?

22. Why are valve actuators used?

23. What is water hammer?

24. What type of valve doesn't require any packing because the stem is not exposed to the liquid?

25. What type/style of valve is designed to protect a water system from excessive internal pressure?

26. Explain the following terms:
    a. W.O.G.

    b. W.P.

    c . S.P.

    d. W.S.P.

27. Explain the following markings that may appear on the valve body:
    125S
    200 WOG

28. List a valve style that is designated for one-direction flow.

29. A valve body is marked "Crane 200." Explain the markings.

30. List a valve type that may be required for liquid, where a very fine control or metering of the fluid would be needed.

Valves Worksheet Answers

1. Starting and stopping flow, throttling flow, check-prevent backflow, regulate pressure, pressure relief.
2. Ball, butterfly, gate.
3. Lift check, swing check, ball check.
4. Ball, butterfly.
5. Bronze, iron, and steel.
6. Cast into the body or on an identification plate on the bonnet.
7. The size, the primary rating, the secondary rating.
8. Where space limits steam travel.
9. It indicates a packing leak.
10. On the outlet side.
11. To reverse the wedge.
12. Lockout the supply valves.
13. Applications that require frequent throttling.
14. Because it allows the valve to be opened easier.
15. Heat damage to seats, pipe strain, and body distortion.
16. Where low pressure and full flow are required.
17. The wafer--surrounded by bolts, and the lug--where the bolts go through.
18. Debur and clean, sling pipes and valve, support hangers, keep valve closed to prevent distortion.
19. To keep crude out of the bonnet.
20. Because it turns to steam and would prevent a perfect solder joint.
21. Removes oxidation.
22. For operation from a central location and interface with other controls.

23. Shock.

24. Diaphragm

25. Relief

26. a. Cold water oil gas
    b. Working pressure
    c. Steam pressure
    d. Working steam pressure

27. 125 steam, 200 cold water oil gas

28. Check valve, left and swing.

29. 200 PSI maximum.

30. Needle valve.

Valves, Packings, and Gaskets Test

True of False:

_____1. Swing type check valves should be used with globe valves.

_____2. A diaphragm valve has packing to prevent product leakage around the stem.

_____3. Butterfly valves are most suited to high pressure service.

_____4. Most globe valves are installed with the pressure above the seat.

_____5. Swing check valves must be installed in a horizontal line.

_____6. More service life can be obtained from a gate valve by reversing the wedge.

_____7. Pipe strain or pulling the pipes into alignment using the valve will render a ball valve inoperable due to twisting.

_____8. A valve will operate satisfactorily at the pressure rating cast into the body at any temperature.

_____9. A major valve should be located as close to the pump as possible.

_____10. A major advantage of a ball valve is the rapid speed of operation.

_____11. A pop safety valve is recommended only for use on liquids.

_____12. A check valve is considered a one-way valve.

_____13. Bronze valves are recommended for high pressures and temperatures in severe service.

_____14. A valve marked "WOG" on the body is for high pressure steam.

_____15. Gate valves are excellent for throttling flow.

_____16. Ball valves are 90-degree valves.

_____17. Butterfly valves are best used for throttling flow.

_____18. Valves work best with the stem in the horizontal position.

_____19. Swing check work best with gate valves.

_____20. Reducing valves decrease the flow but do not effect pressure.

_____21. Gasket material must be matched to the specific requirements of the system.

_____22. Rubber gasket material is suitable for temperatures from 350-500 degrees F.

_____23. Fiber is suitable gasket material for low temperature/low pressure applications.

_____24. Asbestos is suitable for temperatures up to about 800 degrees F.

_____25. Solid metal gaskets are suitable for high pressure/high temperature service.

Fill In:
In the space provided below, identify the kinds of valves and gaskets shown by your instructor.

26. ____________________

27. ____________________

28. ____________________

29. ____________________

30. ____________________

31. ____________________

32. ____________________

33. ____________________

Fill in the Blanks:
34. The most widely used valve is ________________ .

35. The valve that is good for corrosive fluids and high purity application is __________________ .

36. The valve designed primarily for flanged installation is ______________ .

37. The valve generally installed with the line pressure under the disc is _________________ .

38. The valve that may have "INLET" cast on the body is _________________ .

39. ______________ are used to control leakage around the valve stem.

40. For many years, ______________ was used as the major source of packing material.

41. ____________ packings can handle very high pressures but have a low temperature range.

42. ____________ packing is used primarily in hot water, steam, and hot oil valves.

43. The ____________ separates two sets of packings and allows a means of introducing flushing material under pressure.

Multiple Choice:

_____44. A valve body marked "Crane 150" means:
a. 150 pound water rating
b. 150 pound steam rating
c. 150 pound gas rating
d. 150 pound oil rating

_____45. Which of the following valves is used to make a 90 degree turn in a line?
a. ball valve
b. check valve
c. gate valve
d. angle valve

_____46. A valve arrangement which allows stem repacking while the valve is in service:
a. split-seat
b. back-seat
c. rising stem
d. non-rising stem

_____47. A good valve to select for modulation would be:
a. globe valve
b. ball valve
c. needle valve
d. both "a" and "c"

_____48. Valves used at both high temperatures and pressures are made of:
a. plastic
b. bronze
c. carbon steel
d. forged steel

_____49. Bronze valves are most commonly used with:
a. oil
b. gas
c. water
d. steam

_____50. What type of valve has little or no pressure drop?

a. gate
b. ball
c. butterfly
d. all of the above

_____51. Where is the valve identification information located on a valve?

a. on the stem
b. on the bonnet
c. on the disc nut
d. on the seat

Matching:

_____52. Best valve choice for boiler feed lines (disc type).

_____53. Stem type which moves up and down as valve is opened and closed.

_____54. Used for relief of pressure in a liquid system.

_____55. Valve where the bonnet area is sealed off from the body.

_____56. Valve disc type which has relatively soft disc seats of varying materials.

_____57. Valve stem arrangement best suited for areas where headroom is limited.

A. Conventional Disc
B. Check Valve
C. Non-rising Stem
D. Gate Valve
E. Plug-type Valve
F. Lift Check
G. Relief Valve
H. Pop Valve
I. Composition Disc
J. Rising Stem
K. Diaphragm Valve

Matching:

_____58. W.O.G

_____59. Cock

_____60. Pressure Relief

_____61. Bonnet Styles

_____62. Ball Check

_____63. Primary Rating

_____64. Bronze

_____65. Plastic

_____66. Needle Valve

_____67. 1/4 turn operation

A. Suitable for use with chemicals

B. Used to protect water systems

C. O.S. & Y. and N.R.S.

D. Copper, tin, lead and zinc

E. Used for fine metering or flow control

F. Butterfly valve

G. Wet oil and grease

H. Unlubed plug valve

I. Used with heavy viscous fluids

J. Pressure at the temperature of saturated steam.

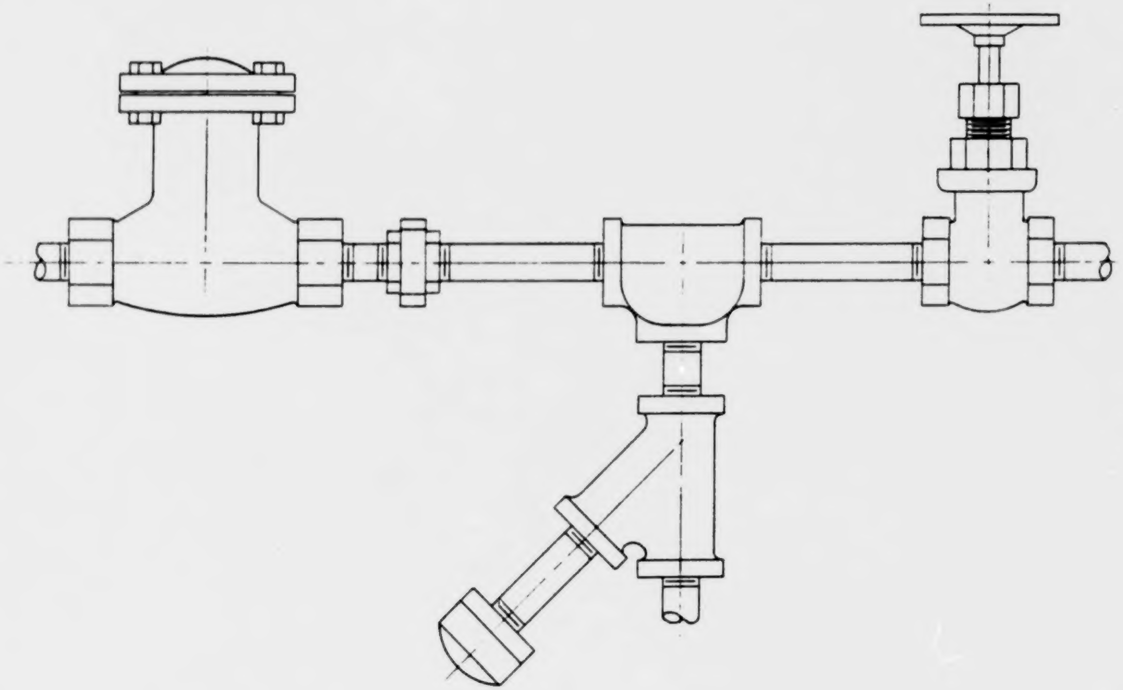
K. Water, oil or gas

Valves, Packings, and Gaskets Test Answers

1. F
2. F
3. F
4. F
5. F
6. T
7. T
8. F
9. F
10. T
11. F
12. T
13. F
14. F
15. F
16. T
17. F
18. F
19. T
20. F
21. T
22. F
23. T
24. T
25. T
26. ________________
27. ________________
28. ________________
29. ________________
30. ________________
31. ________________
32. ________________
33. ________________
34. gate
35. diaphragm
36. butterfly
37. globe
38. check
39. packings
40. asbestos
41. flax
42. copper
43. lantern ring
44. b
45. d
46. b
47. d
48. d
49. c
50. d
51. b
52. E
53. J
54. G
55. K
56. I
57. C
58. K
59. H
60. B
61. C
62. I
63. J
64. D
65. A
66. E
67. F

Wisconsin VTAE

Pipefitting Apprenticeship Curriculum



Apprentice Guide

TO THE APPRENTICE

These introductory pages are prepared to give you an idea of the study that will be expected of you during your apprenticeship.

The courses, prepared and outlined by the school in cooperation with an industrial advisory committee, are intended to give you basic knowledge and understanding in subjects that are allied to your chosen occupation. The content of these courses is felt to be vital and necessary in your training, although not easily taught on the job. This is the foundation of the Wisconsin plan for required related instruction. It is an integral part of your apprenticeship program.

Take full advantage of this opportunity to broaden your understanding while you are preparing for journeymanship in your trade. The knowledge you can obtain through regular school attendance and careful study of the assignments in the courses now will prepare you for future advancement.

JOB DESCRIPTION
For
Industrial Pipefitter

Journeymen in this trade are responsible for the servicing and in some instances the installation of a wide variety of piping systems. Some of the more common areas of maintenance and installation are as follows: process piping systems including layout, design, and fabrication; process steam systems including installing add-ons to steam heating systems; hydraulic and pneumatic equipment including the use of tubing, fittings, sealants, filters, and flow controls; and refrigeration and air conditioning systems including piping/tubing applications and pressurizing, charging, and evacuating a system.

Skills involved to perform this work include: pipe drafting, blueprint reading, templet development, pipe fabrication, soldering, welding, and troubleshooting.

You will be using a variety of tools to assist you in this work. Some are basic tools as pipe wrenches and socket wrenches and some tools are specific to the pipefitting trade. You will also be using a variety of measuring instruments and testing equipment.

This is just a small picture of a very large and demanding trade.

INDUSTRIAL PIPEFITTER

EDUCATIONAL PHILOSOPHY

The field of industrial pipefitting is becoming more technical and comprehensive day-by-day. An individual chosen to enter this field will not only have to learn the present industrial technology, he/she will also have to continually upgrade himself/herself on the new equipment and technology as it evolves.

Accordingly, a completing apprentice is essentially an entry level journeyman with the minimum skills and knowledge of the trade. The learning process has just begun. As a journeyman, the individual should continue to study and attend school and seminars applicable to the trade.

The Wisconsin Schools of Vocational, Technical, and Adult Education believe that the intertwining of practical and theoretical elements serves to provide each individual with the preparation he/she seeks. Our aim is the full development of each individual to advance both the professional and intellectual growth.

We believe that the system for the training of apprentices to become a skilled tradesperson is an effective method of education, therefore, we are committed to working cooperatively with labor and management to carry out this mission.

RESPONSIBILITIES OF THE APPRENTICE

Your responsibilities as an apprentice are important because your training will not be successful if you do not discharge your duties faithfully. Your most critical responsibilities are to fulfill the obligations you pledge to fulfill in your apprenticeship agreement. Specifically, this means that you must be diligent in your efforts to:

a. attend work and related subjects instruction;
b. comply with production, work, testing and training expectations;
c. learn (and practice) the necessary trade skills on the job;
d. learn (and practice) the knowledge and information provided in related subjects instruction;
e. adhere to work expectations about punctuality, dress, working under supervision, taking directions and production schedules;
f. study materials, information and procedures to insure you know what you are doing on the job;
g. observe appropriate safety requirements in all aspects of apprenticeship;
h. attempt to improve your skills at each opportunity; and
i. follow faithfully the rules of the sponsor for whom you work (Rice and Spetz, 1982).

PROGRAM OF EDUCATION

The program of education for industrial pipefitting apprenticeship includes on-the-job training and classroom instruction relative to the trade. On-the-job training provided by the employer enables the apprentice to learn the skills of the trade. Related classroom instruction, provided through the Wisconsin Schools of Vocational, Technical, and Adult Education, gives the apprentice technical instruction in subjects that are pertinent to the development of skilled industrial pipefitters.

The apprentice is required to attend related instruction in V.T.A.E. day school class program in a city near his/her residence. Day school instructional hours are offered on a bi-weekly basis. You may be required to attend classes other than day school as a portion of your related instruction on your time.

Each apprentice will be evaluated during the school year. Grades and attendance reports are given to the employer. These reports evaluate your interest in the trade, cooperation and attitude in the program, whether you are tardy or absent, how you spend your time when you are at school, and how well your assignment work is done.

Textbooks required for the course are to be purchased by the apprentice, not only for apprentice study, but to be used as references in the future as a skilled journeyman pipefitter.

LEARNING IN RELATED SUBJECTS INSTRUCTION

Learning in related subjects requires you to use the same basic strategies that you use to learn on the job, except with a greater emphasis on reading and studying.

The content of related subjects instruction, like the number of hours required, varies by trade or craft. In general the subjects taught include:

a. theory, principles and technical knowledge needed on the job;
b. auxiliary information that assists a worker to better accept and discharge his or her responsibilities;
c. occasional manipulative skills that are important to the craft or trade but are not provided conveniently in the apprentice's on-the-job training.

Often this means that related subjects instruction includes the principles, concepts and applied information that you must know and use from subject matter such as mathematics, general physical sciences, safety, basic measurement, and sketching/blueprint reading. Such information is in addition to study of trade-specific materials and work processes and procedures. Related subjects instruction helps to ensure that you can communicate effectively on the job, can work well in organizations, and know about the apprenticeship system. However, regardless of the trade, craft or situation, the subject matter is current to job demands, practical, applied and directly useful in working in the craft or trade.

What you need to remember about related subjects instruction is that it is not just like the school you used to attend. It is applied information that is important to your career and to your future.

You should attend class regularly, listen, and watch. You must want to learn in order to do so. You must take the subject matter seriously. You must listen to try to understand what the instructor says and demonstrates. As with the job, you must be punctual and must observe the rules and routines set forth for the class.

Seeking information associated with related subjects instruction takes more effort on your part than does seeking information on the job. You must ask questions if you do not know or understand something. Equally important, you must read and study. You will find your reading easier if you follow several simple suggestions including:

1. Decide why the reading is important and what you expect to learn from doing it. How does the reading fit with what you are learning and doing on the job? What information is covered in the materials?

2. What do you expect to remember from reading the material? How does the information fit with what you already know? What are the key points to remember? What kinds of examples that relate to this material can you find from your work?
3. How do you feel about the reading? When will you do the reading? Will you do it quickly or slowly? What kind of schedule must you keep to finish it on time?
4. In terms of the actual reading process, first skim the material and ask yourself questions about the materials you looked over. See if you can identify the major points. Second, read the material carefully. Note each major point and how they fit together. If you encounter problems in your reading, stop to look up words or seek additional information. Third, after you complete your reading, review the materials. Pay particular attention to the major points and to the examples that illustrate these points. Also be sure to answer practice questions and application or self-test exercises included in the text. Again, if there is something you do not understand, reread and ask!

In addition to reading, you also must study related subjects material. Several techniques that will help you to study effectively include:

1. Keep up with assignments. Do the work that is expected each day and week. Avoid getting hopelessly behind. More importantly, if you keep up, you will see a better association between what you are studying and what you are doing on the job. One strategy for helping you to keep up is to make a weekly schedule of things to do and when to do them. Keep up with the schedule. Continue studying until you complete a task and can mark something off your list. This also helps you to keep track of assignments and assists you to set realistic goals. Initially allow more time than you think you will need to do a job.
2. Find a standard place and time to study. Set aside a space at a desk or table and spend a few minutes each day in that spot doing your work. Further, if you can use about the same time period each day doing the work, you will find it easier to concentrate and to get things done.
3. Concentrate. Start by spending a few minutes each day rereading the major points from previous, associated lessons. Then, as you work through new materials, avoid distractions.
4. Do your best. All anyone will ask of you is that you do your best. Set realistic goals and work to achieve them. Do not sluff-off work or quit just because you do not want to do it. Make an honest effort. You will find that you can learn most things.

Applying information means working through the problems and questions, reviewing the information, seeking samples on the job, and looking to apply the instructions on the job. You, your related instructor and your job supervisor must work on these together (Rice and Spetz, 1982).

The specific related training sequence you should use for this course is the following:

1. Read unit competencies.
2. Read objectives for the unit.
3. Take any pre-test which may be required of a unit.
4. Complete all reading assignments.
5. Complete all classroom activities.
6. Complete all unit application exercises.
7. Complete unit evaluation/checkout.
8. Proceed to next unit and follow this same sequence.

Reference:

1. Rice, E. and Spetz, S. Introduction to Apprenticeship. Raleigh, North Carolina: Conserva, Inc., 1982.

Apprentice Guides

On the following pages is a copy of the Apprentice Guide for each of the units. The apprentices should be given a copy of the appropriate guide as the corresponding unit is begun.

Competency:

1. Describe fundamental communication skills and how they influence work in the trade.

Instructional Objectives:

1. Identify elements of a communication.
2. Describe types of non-verbal communication.
3. Define feedback.
4. Describe factors that frequently contribute to poor listening and understanding.
5. Identify procedures for improving listening skills.
6. Describe techniques for asking questions.

Learning Activities:

1. Read Chapters 2, 3, and 4 in Interpersonal Skills and Communication - Apprenticeship Related Instruction.
2. Complete the Self-Test Exercises at the end of each chapter.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Competency:
1. Demonstrate safe practices necessary in the trade.

Instructional Objectives:
1. Describe safety awareness.
2. Identify causes of accidents.
3. Define unsafe acts.
4. Describe safety planning.

Learning Activities:
1. Read the General Safety Information Sheet.
2. Complete the General Safety Self-Test.

Evaluation/Checkout:
1. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Recognize safe use of tools and equipment used in the trade.
2. Identify proper procedures and potential problems of ladder and scaffold use.
3. Recognize equipment and clothing used to protect against hazards in the work environment.

Instructional Objectives:

1. Identify unsafe work situations involving tools and equipment.
2. List safe work practices for using tools and equipment.
3. Identify how to develop safety skills.
4. List the consequences of unsafe work habits.
5. Select typical hazards associated with ladder and scaffold use.
6. Identify appropriate safety procedures for using ladders and scaffolds.
7. List situations where protective equipment or clothing is needed to work safely.
8. Explain the hazards of not using protective devices or clothing properly.
9. Identify some of the types of protective clothing and equipment available for use.

Learning Activities:

1. Read Chapters 3, 4, and 5 in Basic Safety II - Apprenticeship Related Instruction.
2. Complete the Self-Test Exercises at the end of each chapter.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate safe and effective use of typical hand and power tools used in the trade.

Instructional Objectives:

1. Identify safe practices for the use of common hand tools used in the trade.
2. Identify safe practices for the use of common power tools used in the trade.

Learning Activities:

1. Read Hand Tool Safety Information Sheet.
2. Read Power Tool Safety Information Sheet.
3. Complete the Hand Tool Safety Self-Test.
4. Complete the Power Tool Safety Self-Test.
5. View the videotape "Electronic Tool Catalog" (Wheeler Manufacturing Corporation).

Application Exercises:

1. Demonstrate the safe use of a stationary grinder.
2. Demonstrate the safe use of a portable grinder.
3. Demonstrate the safe use of a metal-cutting band saw.
4. Bevel pipe with a grinder
5. Cut, ream, and thread pipe with a threading machine.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the use of the methods of measurement used in the trade.

Instructional Objectives:

1. Identify measuring instruments.
2. Read the sixteenth's rule.
3. Complete statements concerning rules for the use of calipers.
4. Read a micrometer.
5. Measure lines to the nearest quarter, eighth, and sixteenth of an inch.
6. Read a rule.
7. Measure inside and outside diameters.
8. Use the inside and outside calipers.
9. Read the micrometer settings.

Learning Activities:

1. Discuss in class sessions the Information Sheet from Section C - Unit III "Measuring" from Air Conditioning and Refrigeration Fundamentals.
2. Complete Assignment Sheet 1, "Measure Lines to the Nearest Quarter, Eighth and Sixteenth of an Inch," Assignment Sheet 2, "Read a Rule," Assignment Sheet 3, "Measure Inside and Outside Diameters," Assignment Sheet 5, "Use the Inside and Outside Calipers," and Assignment Sheet 6, "Read the Micrometer Settings."

Evaluation/Checkout:

1. Submit Assignment Sheets 1, 2, 3, 5, and 6.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a joint.
3. Demonstrate the ability to silver braze joints and silver braze a copper to a steel joint.

Instructional Objectives:

1. Match terms related to soldering and welding equipment with their definitions.
2. Identify safety rules for using soldering and welding equipment.
3. Complete a list of statements concerning lighting, adjusting, and extinguishing the air-acetylene torch.
4. Arrange in order the steps for setting up the oxyacetylene torch.
5. Arrange in order the steps for lighting, adjusting, and extinguishing the oxyacetylene torch.
6. Demonstrate the ability to light and adjust the air-acetylene torch.
7. Match terms related to soft soldering with their definitions.
8. Arrange in order the steps in making a solder joint.
9. Distinguish between types of flux for soft solder.
10. List four conditions for creating capillary actions of solders.
11. Demonstrate the ability to clean, flux, and solder a joint with the air-acetylene torch.
12. Demonstrate the ability to clean, flux, and solder a joint with the oxyacetylene torch.
13. Match terms related to silver brazing with their definitions.
14. Match types of silver brazing alloys with their alloys and characteristics.
15. Select true statements concerning guidelines for using silver solder flux.
16. Match different temperature ranges with their correct flux characteristics.
17. Arrange in order the steps in using the air-acetylene high temperature wraparound tip for silver brazing.
18. Demonstrate the ability to silver braze a tube and fitting with a oxyacetylene torch.
19. Demonstrate the ability to silver braze a copper to a steel joint.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section E - Units I, II, and III, "Soldering and Welding Equipment," "Soft Soldering," and "Silver Brazing" from Air Conditioning and Refrigeration Fundamentals.
2. View the videotape "Brazing and Braze Welding" (Industrial Training Corporation).
3. Observe as your instructor demonstrates the proper use of soldering and welding equipment and demonstrates soft soldering and silver brazing.

Application Exercises:

1. Light and adjust the air-acetylene torch.
2. Clean, flux, and solder a joint with the air-acetylene torch.
3. Soft solder with the oxyacetylene torch.
4. Silver braze a tube and fitting with an oxyacetylene torch.
5. Silver braze a copper to a steel joint.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate general safe practices for handling chemicals.
2. Demonstrate the ability to withdraw chlorine and/or caustic soda from containers.

Instructional Objectives:

1. Outline the emergency measures and procedures to be used in working with chlorine.
2. Identify first aid procedures to be used in case of chlorine exposure.
3. List the way chlorine shipments are received and handled.
4. Outline the proper procedure for withdrawing chlorine from containers.
5. Identify components of piping systems for chlorine.
6. Identify first aid procedures to be used in case of caustic soda exposure.
7. Outline the emergency measures and procedures to be used in working with caustic soda.
8. Outline the proper procedure for withdrawing caustic soda from containers.
9. Use the proper procedure to withdraw chlorine and/or caustic soda from containers.

Learning Activities:

1. Read Chapters 2, 4, 5, 6, and 7 in Chlorine from PPG Industries, Inc.
2. Read Chapters 3, 4, 5, and 6 in Caustic Soda from PPG Industries, Inc.
3. View the videotape "Chlorine Safety" (NUS Training Corporation) and the film "Be Careful With Caustic" (PPG Industries, Inc.).
4. Complete the Chemical Handling Worksheet.

Application Exercises:

1. Use the proper procedure to withdraw chlorine and/or caustic soda from containers.

Evaluation/Checkout:

1. Submit Chemical Handling Worksheet.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe various types of hot water heating systems.
2. Identify types of boilers and appropriate safety devices for hot water heating systems.
3. Explain venting and piping considerations for hot water heating systems.
4. Demonstrate the ability to maintain a hot water heating system.

Instructional Objectives:

1. Explain the operation of a one-pipe hot water heating system.
2. Explain the operation of a two-pipe direct return and a two-pipe reverse return hot water heating system.
3. Explain the operation of a series loop hot water heating system.
4. Explain why forced circulation hot water heating is preferred over gravity circulation.
5. Identify the various hot water heating fittings and accessories that are necessary for safe and efficient operation.
6. Describe the role of the expansion tank in a hot water heating system.
7. Explain the advantages and disadvantages of hot water heating over steam heating systems.
8. Explain how to remove all the air from hot water heating systems.
9. Draw and explain how to make proper piping connections for four types of hot water heating systems.
10. Troubleshoot a hot water heating system that is not operating properly.
11. Install a pressure reducing valve on a hot water heating system.
12. Install a stop valve on a hot water heating system.
13. Install a safety relief valve on a hot water heating system.

Learning Activities:

1. Read Chapter 7 and pp. 519-542 in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Hydronic Heating" - Lecture 10 and pp. 28-39 in "Boiler Fittings" - Lecture 3 in Building Systems Technician - Course 2.
2. Read "Basic Controls for Hot Water Boilers" (Bulletin SL-BCHW) from McDonnell and Miller, ITT Corporation.
3. Read Hot Water Heating Systems Troubleshooting Information Sheet.
4. Complete Assignment 1 - "Diagram a One-Pipe Hot Water Heating System."
5. Complete Assignment 2 - "Diagram a Two-Pipe Direct Return and Two-Pipe Reverse Return Hot Water Heating System."
6. Complete Assignment 3 - "Diagram a Series-Loop Hot Water Heating System."
7. Complete Assignment 4 - "Diagram a Hot Water Heating Boiler."

Application Exercises:

1. Troubleshoot a hot water heating system that is not operating properly.
2. Install a pressure reducing valve on a hot water heating system.
3. Install a stop valve on a hot water heating system.
4. Install a safety relief valve on a hot water heating system.

Evaluation/Checkout:

1. Submit Assignment Sheets 1, 2, 3, & 4.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the basic principles involved in hydraulic system operation.
2. Describe the advantages and disadvantages of a hydraulic system.
3. Summarize safety practices for working on hydraulic systems.
4. Explain how the principles of pressure and flow are used in hydraulic systems.
5. Identify hydraulic system symbols.

Instructional Objectives:

1. State Pascal's Law.
2. Define pressure.
3. List advantages and disadvantages of a hydraulic system.
4. Name six hazards to safety when working with hydraulic systems.
5. List five safety practices when working on hydraulic systems.
6. Define what is meant by conservation of energy.
7. Explain what a prime mover is.
8. Calculate pressure when given force and area.
9. Name the output and input components of a hydraulic system.
10. Identify the characteristics of petroleum oil which make it suitable as a hydraulic fluid.
11. Estimate the pressure at the bottom of a column of oil.
12. State what is definitely known about the pressure on opposite sides of an orifice when oil is flowing through it.
13. Describe the function and operation of the pump in a hydraulic system.
14. Explain how pressure is created in a hydraulic system.
15. State why loss of pressure is usually not a symptom of pump malfunction.
16. State the formula for figuring pressure developed when moving a load with a cylinder.
17. Identify what determines the speed of an actuator.
18. Explain the relationship between fluid, velocity, and friction in a pipe.
19. Outline the relationship between pressure, force, and area in a hydraulic system.
20. Describe how the concepts of work and power are used in a hydraulic system.
21. Identify the components of a basic hydraulic circuit.
22. Distinguish between a hydrodynamic and a hydrostatic device.
23. List two ways which create a tendency for a liquid to flow.
24. Explain the meaning of a pressure "head."
25. Determine atmospheric pressure in psia, psig, inches of mercury, and feet of water.
26. Name two ways to measure flow.
27. Explain what happens when liquid is subject to different pressures.
28. Describe how pump working pressure is determined.
29. Define laminar flow.
30. Identify causes of turbulent flow.

31. State Bernoulli's theorem.
32. Name three kinds of working lines and tell what each does.
33. Identify two forms of energy found in the hydraulic fluid.
34. Match terms associated with fundamentals of hydraulics with their correct definitions.
35. Select statements concerning the power transfer in a hydraulic system.
36. Draw a block diagram of a simple hydraulic system.
37. Draw a symbolic diagram of a simple hydraulic system.

Learning Activities:

1. Read Chapters 1 and 2 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units I and II in Hydraulics.
3. Complete the Review Questions at the end of Chapters 1 and 2 in the Industrial Hydraulics Manual.
4. View the videotapes "The Physical World of a Machine" and "Hydraulic Transmission of Force and Energy" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.
6. Complete Assignment Sheet 1, "Draw a Block Diagram of a Simple Hydraulic System."
7. Complete Assignment Sheet 2, "Draw a Symbolic Diagram of a Simple Hydraulic System."

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit Assignment Sheets 1 and 2.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the purpose and characteristics of hydraulic fluid.
2. Explain how reservoirs and filters are used in a hydraulic system.
3. Identify components of reservoirs and filters.
4. Demonstrate the ability to clean and inspect a reservoir.

Instructional Objectives:

1. List four primary functions of the fluid in hydraulic systems.
2. Name four quality properties of a hydraulic fluid.
3. Define viscosity.
4. Identify the effects of temperature on the viscosity of hydraulic fluids.
5. Describe what the viscosity index is.
6. Name several catalysts to oxidation of hydraulic oil.
7. Name common additives in hydraulic systems.
8. Define demulsibility.
9. List three factors that determine the properties of a hydraulic oil.
10. List three basic types of fire-resistant hydraulic fluid.
11. List six safety rules to remember when working with hydraulic fluid.
12. Define reservoir.
13. Identify two types of reservoirs.
14. List three functions of a reservoir.
15. Identify the parts of a properly designed, vented reservoir.
16. Identify the parts of a properly designed, pressurized reservoir.
17. Demonstrate the ability to clean and inspect a vented reservoir.
18. List the functions of a filter.
19. Identify the effects of contaminants in the hydraulic system.
20. Define mesh and micron ratings.
21. Name three possible locations for a filter.
22. Identify types of filter circuits.
23. Distinguish between surface filters and depth filters.
24. Identify factors used in specifying a filter.
25. Name three different types of filtering material.
26. Define full-flow.
27. Explain the purpose of an indicator type filter.

Learning Activities:

1. Read Chapters 3 and 5 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units III and VI in Hydraulics.
3. Complete the Review Questions at the end of Chapters 3 and 5 in the Industrial Hydraulics Manual.
4. View the videotape "Fluids, Reservoirs, Coolers, and Filters" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Clean and inspect a vented reservoir.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the types of pipe/tubing and fittings used to carry hydraulic fluids.
2. Describe the types of seals and seal materials required for hydraulic application.
3. Explain how leaks can be prevented in hydraulic systems.
4. Demonstrate the ability to work with pipe/tubing/hose used in hydraulic systems.
5. Demonstrate the ability to install seals for hydraulic components.

Instructional Objectives:

1. Describe how pipe size is specified.
2. Identify the schedule number of standard pipe.
3. Identify the types, construction, and size of steel tubing.
4. Identify types of fittings used in hydraulic systems.
5. List the advantages of tubing over pipe.
6. Identify types of fittings commonly used with tubing.
7. List characteristics of hydraulic hose.
8. Identify types of hose ends used in hydraulic systems.
9. Name two reasons for pipe support.
10. List factors to consider when routing tubing in hydraulic systems.
11. List conditions to avoid when routing hydraulic hose.
12. Demonstrate the ability to replace a reusable hose end.
13. Define positive seal.
14. Describe two types of leakage paths in hydraulic systems.
15. Explain the meaning of static sealing application.
16. Identify types of sealing devices used in hydraulic systems.
17. List types of seals and their applications.
18. Identify types of seal construction and when each type is used.
19. Define elastomer.
20. Identify seal materials.
21. List factors to consider concerning seal material.
22. Name three general ways to prevent leakage.
23. Explain the meaning of back-mounting.
24. List five operating factors that affect seal life.
25. Demonstrate the ability to install an O-ring.
26. Demonstrate the ability to install a seal.
27. Demonstrate the ability to install a packing.
28. Demonstrate the ability to cut, flare, bend, swage, and ream tubing.

Learning Activities:

1. Read Chapter 4 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units IV and V in Hydraulics.
3. Complete the Review Questions at the end of Chapter 4 in the Industrial Hydraulics Manual.
4. Read Know Your Hoses, Tubing, and Fittings.
5. View the videotapes "Tube Fittings," "Preventing Hose and Coupling Failures" and "Threaded Fasteners" (Industrial Training, Inc.).
6. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Demonstrate the ability to replace a reusable hose end.
2. Demonstrate the ability to install an O-ring.
3. Demonstrate the ability to install a seal.
4. Demonstrate the ability to install a packing.
5. Demonstrate the ability to cut, flare, bend, swage, and ream tubing.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the purpose of hydraulic actuators and identify the different types.
2. Indicate how a hydraulic actuator is chosen for a particular application.
3. Demonstrate the ability to repair a hydraulic cylinder.

Instructional Objectives:

1. Describe the operation of a hydraulic cylinder.
2. Distinguish between the operation of a single-acting and double-acting cylinder.
3. Identify types of double-acting cylinders.
4. Identify the parts of a single-acting cylinder.
5. Identify the parts of a double-acting cylinder.
6. List sources of common failures of hydraulic cylinders.
7. Given a formula, calculate the force output of a hydraulic cylinder.
8. Given a formula, calculate the speed of a hydraulic cylinder.
9. Given a formula, calculate the power output of a cylinder.
10. Given a formula, calculate the flow rate required to move a cylinder a given distance in a given time.
11. Demonstrate the ability to disassemble, inspect, and reassemble a hydraulic cylinder.
12. Demonstrate the ability to test a cylinder for internal and external leakage.
13. Define displacement and torque ratings of a hydraulic motor.
14. Name three kinds of hydraulic motors.
15. Contrast gear motors with vane motors in terms of how torque is developed in each.
16. Given a formula, calculate hydraulic motor load torque.
17. Given a formula, calculate the displacement of a hydraulic motor.
18. Given a formula, calculate the speed of a hydraulic motor.
19. Given a formula, calculate hydraulic motor inlet pressure.
20. Given a formula, calculate hydraulic motor input and output power.
21. Given a formula, calculate motor overall efficiency.
22. Explain the operation of a gear motor.
23. Explain the operation of vane motors.
24. Name three types of piston motors.
25. Explain the operation of an in-line axial piston motor.
26. Compare the efficiency of the various types of hydraulic motors.

Learning Activities:

1. Read Chapter 6 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units IX and X in Hydraulics.
3. Complete the Review Questions at the end of Chapter 6 in the Industrial Hydraulics Manual.
4. View the videotapes "Hydraulic Actuators" and "Hydraulic Motors" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Demonstrate the ability to disassemble, inspect, and reassemble a hydraulic cylinder.
2. Demonstrate the ability to test a cylinder for internal and external leakage.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the function and operation of directional controls, pressure controls, and volume controls in a hydraulic system.
2. Determine what type of control is necessary for a particular application.
3. Demonstrate the ability to repair/install hydraulic controls.

Instructional Objectives:

1. Describe the function of a directional control.
2. Identify types of directional control valves.
3. Explain what is meant by finite positioning.
4. Explain the function of a check valve.
5. Distinguish between the operation of a check valve and a spool direction control valve.
6. Describe the operation of a pilot-operated check valve.
7. Name three ways to shift a four-way valve.
8. Describe the flow paths in a directional control valve controlling a cylinder.
9. Distinguish between open-center and closed-center systems.
10. Identify types of actuators for directional control valves.
11. Explain how pilot pressure may be created for an open-center, pilot-operated valve.
12. Describe the function of a pilot choke.
13. Describe the operation of a mechanical servo valve.
14. Describe the operation of a electro-hydraulic servo valve.
15. Identify the primary feature which makes a servo valve different from an ordinary valve.
16. Name three types of pressure control valves.
17. Define cracking pressure.
18. Identify types of pressure relief valves when given a description of their operations.
19. Explain what is meant by venting the relief valve.
20. Describe the operation of "R" type valves.
21. Name three applications of the "R" valve.
22. Name three applications of the "RC" valve.
23. Identify operational characteristics of a pressure reducing valve.
24. List three types of flow control valves.
25. Identify an application for each of the three types of flow control valves.
26. List the two categories of flow control valves.
27. Differentiate between a by-pass and restricted type flow control.
28. Identify operational characteristics of a pressure compensated flow control valve.
29. Identify when temperature compensation might be needed.

30. Name the advantage of the flow control and relief valve over a conventional flow control.
31. Demonstrate the ability to disassemble, inspect, and reassemble a pressure control valve.
32. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve.
33. Demonstrate the ability to disassemble, inspect, and reassemble a flow control valve.

Learning Activities:

1. Read Chapters 7,8,9, and 10 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheet from Unit VIII in Hydraulics.
3. Complete the Review Questions at the end of Chapters 7,8,9, and 10 in the Industrial Hydraulics Manual.
4. View the videotapes "Control of Hydraulic Energy," "Flow Control Valves," "Check Valves, Accumulators and Cylinders," "Directional Control Valves," "Pressure Control Valves," and "Pilot Operated Pressure Control Valves" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.

Application Exercises:

1. Demonstrate the ability to disassemble, inspect, and reassemble a pressure control valve.
2. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve.
3. Demonstrate the ability to disassemble, inspect, and reassemble a flow control valve.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the function and operation of the various types of pumps used in a hydraulic system.
2. Perform various calculations concerning pump operation.
3. Demonstrate the ability to repair/install hydraulic pumps.

Instructional Objectives:

1. Explain why a centrifugal pump would not be used to transmit pressure.
2. Distinguish between positive and nonpositive displacement pumps.
3. Describe the basic characteristics of positive displacement pumps.
4. Name kinds of positive displacement pumps.
5. Explain what a pump's pressure rating means.
6. State two ways of expressing pump size.
7. Given the formula, calculate pump displacement.
8. Given the formula, calculate pump flow rate.
9. Given the formula, calculate pump input and output power.
10. Calculate pump volumetric efficiency.
11. List the advantages and disadvantages of gear pumps.
12. Identify the operational characteristics of vane pumps.
13. Distinguish between an axial and radial piston pump.
14. Identify the operational characteristics of a radial piston pump.
15. Name two types of axial piston pumps.
16. Describe the construction and operation of axial piston pumps.
17. Identify the operational characteristics of a variable displacement axial piston pump.
18. Identify the parts of a servo-controlled variable displacement pump.
19. Match the components of pressure compensated axial piston pumps with their functions.
20. List four causes of hydraulic pump cavitation.
21. List common causes of hydraulic pump failure.
22. Demonstrate the ability to disassemble, inspect, and reassemble a gear pump.
23. Demonstrate the ability to disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

Learning Activities:

1. Read Chapter 11 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheet from Unit VII in Hydraulics.
3. Complete the Review Questions at the end of Chapter 11 in the Industrial Hydraulics Manual.

4. View the videotapes "Operation at the Suction Side of a Pump" and "Hydraulic Pumps" (Parker Hannifin).
5. Participate in sessions on a hydraulics trainer as provided by your instructor.
6. Complete Assignment 1, "Calculate Pump Displacement, Flow Rate, Input and Output Power, and Overall Efficiency."

Application Exercises:

1. Demonstrate the ability to disassemble, inspect, and reassemble a gear pump.
2. Demonstrate the ability to disassemble, inspect, and reassemble a pressure compensated variable displacement pump.

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit Assignment Sheet 1.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the purpose and operation of accumulators, coolers, heaters, and intensifiers used in a hydraulic system.
2. Identify measurement instruments used in a hydraulic system.
3. Describe the components of a basic hydraulic circuit.
4. Identify the symbols used in a hydraulic circuit.
5. Identify applications of hydraulic circuits.
6. Draw hydraulic circuits.

Instructional Objectives:

1. List functions of an accumulator.
2. Identify types of accumulators.
3. List safety precautions for working with accumulators.
4. Explain reasons for using a cooler.
5. Describe types of coolers.
6. List common failures of coolers.
7. Explain reasons for using a heater.
8. Describe two types of heaters.
9. List two common failures of heaters.
10. Describe the purpose of an intensifier.
11. List three situations where a pressure gauge might be required.
12. Explain how vacuum gauges are calibrated.
13. Identify the components of a basic hydraulic circuit.
14. Distinguish between types of hydraulic circuits.
15. Identify the symbols used in a hydraulic circuit.
16. Identify applications of hydraulic circuits.
17. List the advantages and disadvantages of open-center and closed-center systems.
18. Draw an open-center hydraulic circuit.
19. Show the oil flow in a circuit.

Learning Activities:

1. Read Chapters 12 and 13 in the Industrial Hydraulics Manual.
2. Discuss in class sessions the Information Sheets from Units XI and XII in Hydraulics.
3. Complete the Review Questions at the end of Chapters 12 and 13 in the Industrial Hydraulics Manual.
4. Participate in sessions on a hydraulics trainer as provided by your instructor.
5. Complete Assignment 1, "Draw an Open-Center Hydraulic Circuit."
6. Complete Assignment 2, "Show the Oil Flow in a Circuit."

Evaluation/Checkout:

1. Submit your answers to the Review Questions.
2. Submit Assignment Sheets 1 and 2.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the ability to troubleshoot and maintain hydraulic systems.
2. Demonstrate the ability to diagnose and test hydraulic systems.

Instructional Objectives:

1. Name three reasons for performing preventive maintenance.
2. List four factors that can damage a hydraulic system.
3. Identify key maintenance problems.
4. List steps in keeping the hydraulic system clean.
5. List steps to be performed for general maintenance of a hydraulic system.
6. Demonstrate the ability to perform general maintenance procedures on a hydraulic system.
7. Demonstrate the ability to change hydraulic fluid and filters.
8. Define terms associated with diagnosis and testing.
9. Arrange in order the steps in troubleshooting.
10. Identify the types of hydraulic system testers.
11. List problems and remedies for inoperative systems.
12. List problems and remedies for systems that operate erratically.
13. List problems and remedies for systems that operate slowly.
14. List problems and remedies for systems that operate too fast.
15. List problems and remedies for systems that overheat.
16. List problems and remedies for foaming fluid.
17. List problems and remedies for excessive pump noise.
18. List problems and remedies for leaking pumps.
19. List problems and remedies for load drop when the control valve is in the neutral position.
20. List problems which can cause the control valve to stick or work hard.
21. Identify problems which can cause a control valve to leak.
22. List problems which can cause a cylinder to leak.
23. List problems which can cause a cylinder to actually lower when the control valve is moved to slowly raise a cylinder.
24. Demonstrate the ability to test a hydraulic pump.
25. Demonstrate the ability to locate a problem in a hydraulic system.
26. Demonstrate the ability to test a relief valve.
27. Demonstrate the ability to test a control valve.
28. Demonstrate the ability to test an actuator.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Units XIII and XIV in Hydraulics.
2. Participate in sessions on a hydraulics trainer as provided by your instructor.
3. View the videotape series - Troubleshooting Hydraulics (Tel-A-Train).

Application Exercises:

1. Demonstrate the ability to perform general maintenance procedures on a hydraulic system.
2. Demonstrate the ability to change hydraulic fluid and filters.
3. Demonstrate the ability to test a hydraulic pump.
4. Demonstrate the ability to locate a problem in a hydraulic system.
5. Demonstrate the ability to test a relief valve.
6. Demonstrate the ability to test a control valve.
7. Demonstrate the ability to test an actuator.

Evaluation/Checklist:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
1. Evaluate different types of insulation that are used in the pipefitting trade.
2. Demonstrate the ability to repair and install insulation.

Instructional Objectives:
1. Define terms that are used in describing insulating material.
2. Explain reasons for insulating.
3. Identify characteristics of insulating materials.
4. Describe different types of insulation.
5. Describe different types of lagging materials.
6. Identify the uses of insulation and lagging materials.
7. Describe the installation procedures for using insulation.
8. Identify insulation requirements when installing insulation materials.
9. List installation procedures in regard to the application and maintenance of insulation.
10. Install/repair insulation on piping in a process steam system.
11. Install/repair insulation on valves and fittings in a process steam system.

Learning Activities:
1. Read Insulation Information Sheet.
2. Read "Foamglas Insulation Systems" from Pittsburgh Corning.
3. Review the tables in Chapter 14 of Pipe Fitting and Piping Handbook.
4. View the videotape "Insulation - Covering Hot Piping" (Marshall Maintenance Production), or the videotape "Thermal Insulation" (NUS Training Corporation).

Application Exercises:
1. Install/repair insulation on piping in a process steam system.
2. Install/repair insulation on valves and fittings in a process steam system.

Evaluation Checkout:
1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
Perform calculations in basic arithmetic.

Instructional Objectives:
1. Add, subtract, multiply, and divide whole numbers.
2. Identify fraction types and convert improper fractions to proper fractions in their lowest terms.
3. Identify common denominators in fractions.
4. Add, subtract, multiply, and divide fractions.
5. Add, subtract, multiply, and divide decimals.
6. Change decimals to fractions.
7. Change fractions to decimals.
8. Convert inches to decimals of a foot.
9. Convert decimals of a foot to inches.

Learning Activities:
1. Complete the Basic Mathematics Pretest. For a score of 90% or better, skip to Math II. For a score under 90%, complete Math I.
2. Read Units 1-12 in *Basic Industrial Mathematics*.
3. Complete all the Assignments in Units 1-12.

Evaluation/Checkout:
1. Submit the Assignments from Units 1-12.
2. Demonstrate your knowledge of the objectives by completing a test .

Competency:
Perform calculations in basic geometry.

Instructional Objectives:
1. Measure the distance between points.
2. Calculate the circumference of a circle.
3. Calculate the perimeters of squares, rectangles, and triangles.
4. Calculate the surface area of squares, rectangles, triangles, and circles.
5. Compute squares and square roots.
6. Calculate the volumes of cubes, rectangles, and cylinders.

Learning Activities:
1. Read Units 17-23 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 17-23.

Evaluation/Checkout:
1. Submit the Assignments from Units 17-23.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
Perform calculations in basic algebra.

Instructional Objective:
1. Solve equations by addition or subtraction.
2. Solve equations by multiplication or division.
3. Solve problems dealing with ratios.
4. Set up equations to solve proportions.
5. Solve percentage problems.

Learning Activities:
1. Read Units 13-16 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 13-16.

Evaluation/Checkout:
1. Submit the Assignments from Units 13-16.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
1. Perform calculations using right triangles.
2. Perform calculations in trigonometry and generalize their solutions to the trade.

Instructional Objectives:
1. Apply the terminology that is used to name the sides and angles in triangle problems.
2. Calculate the missing angles in triangles when two angles are known.
3. Solve for missing sides of right triangles using the Pythagorean Theorem.
4. Use ratios to understand the relationships between sides of triangles.
5. Identify the six trigonometric functions.
6. Use trigonometric tables to calculate the values for different angles.
7. Use trigonometric tables to calculate the angles to the nearest minute for different values.
8. Use trigonometry to find the missing sides of right triangles.
9. Use trigonometry to find the missing angles of right triangles.
10. Solve piping problems using trigonometry.

Learning Activities:
1. Read Units 24-29 in Basic Industrial Mathematics.
2. Complete all the Assignments in Units 24-29.
3. Complete Worksheets 1-7.

Evaluation/Checkout:
1. Submit the Assignments from Units 24-29.
2. Submit Worksheets 1-7.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Interpret basic electricity theory and practice as it relates to troubleshooting, repair, and maintenance.

Instructional Objectives:

1. Distinguish between amperes, volts, and ohms.
2. Identify direct current and alternating current.
3. Identify different types of electric service.
4. Describe the importance of making sure that motor ratings are matched to the voltage and phase characteristics of the electrical system.
5. Explain the purpose of switches, circuit breakers, and fuses.
6. Explain the purpose of grounding in electrical systems.
7. Identify safe practices when working with electricity.
8. Identify the effects of electric shock.

Learning Activities:

1. Read What a Journeyman Should Know About Electricity from the National Association of Plumbing, Heating and Cooling Contractors.
2. View the videotapes "Plant Science - 5: Electrical Energy" (NUS Training Corporation) and "Electrical Safety" (Tel-A-Train).
3. View the videotapes "Electrical Equipment - 1" and "Electrical Equipment - 2" (NUS Training Corporation) instead of "Plant Science - 5: Electrical Energy."
4. Complete the Electrical Systems Worksheet.

Evaluation/Checkout:

1. Submit Electrical Systems Worksheet
2. Demonstrate your knowledge of the objectives by completing a test.

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Competency:

1. Describe energy and its relationship to work, power, and efficiency.

Instructional Objectives:

1. Define energy.
2. Define work, power, and efficiency.
3. Describe the relationship between work, power, and efficiency.
4. Explain how heat is converted to power.
5. Solve efficiency problems.

Learning Activities:

1. Read Chapter 6, "Energy" in Conceptual Physics by Paul Hewitt.
2. Read the Information Sheet on Energy.
3. View the videotapes "Energy Conversion" (NUS Training Corporation) and "Plant Science - 6: Science Fundamentals" (NUS Training Corporation).
4. Complete the Energy Worksheet.

Evaluation/Checkout:

1. Submit the Energy Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify the states of matter.
2. Define the properties of solids, liquids, and gases, and perform work related calculations dealing with these properties.

Instructional Objectives:

1. Define matter.
2. Describe the three states of matter.
3. Define element and atom.
4. Define density and elasticity.
5. Distinguish among tensile stress, compressive stress, shear stress and strain.
6. Explain factor of safety for a material.
7. Solve problems dealing with states of matter.
8. Explain Pascal's Law.
9. Explain the operation of an open manometer.
10. State the construction and operation of a bourdon tube gage.
11. Solve problems concerned with liquids at rest and in motion.
12. Explain Bernoulli's Principle.
13. Define viscosity.
14. Differentiate between pressure drop and velocity pressure.
15. Define surface tension.
16. Define buoyancy.
17. State Archimedes' Principle.
18. Explain and apply the specific weight concept.
19. Solve specific weight and density problems.
20. Differentiate between specific gravity and specific weight.
21. Explain what the atmosphere is.
22. Define venturi and explain what it is used for.
23. Define Boyle's Law.
24. Describe the operation of a barometer.
25. Solve problems using absolute and gauge pressure.

Learning Activities:

1. Read Chapter 10, "The Atomic Nature of Matter," Chapter 11, "Solids," Chapter 12, "Liquids," and Chapter 13, "Gases and Plasmas" in Conceptual Physics by Paul Hewitt.
2. Read the Properties of Matter I Information Sheet.
3. Read the Properties of Matter II Information Sheet.
4. Read the Properties of Matter III Information Sheet.
5. View the videotapes "Plant Science - 2: Properties of Matter" (NUS Training Corporation) and "Plant Sciences - 4: Process Dynamics" (NUS Training Corporation) or "Properties and Fluid Flow" (NUS Training Corporation) and "Pressure" (NUS Training Corporation).
6. Complete the Properties of Matter I Worksheet.
7. Complete the Properties of Matter II Worksheet.
8. Complete the Properties of Matter III Worksheet.

Evaluation/Checkout:

1. Submit the Properties of Matter I, II, and III Worksheets.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Interpret the relationship among temperature, heat, and expansion.
2. Describe heat transfer.

Instructional Objectives:

1. Differentiate between heat and temperature.
2. Explain what a BTU is.
3. Define specific heat.
4. Explain the concept of expansion.
5. Describe what a bimetal is.
6. Solve problems concerned with the expansion of metals.
7. Solve problems concerned with the relationship between temperature and pressure.
8. Define conduction, convection, and radiation.
9. Explain Newton's Law of Cooling.
10. Explain "the greenhouse effect."
11. Solve problems dealing with the relationship between temperature, volume, and pressure.

Learning Activities:

1. Read Chapter 14, "Temperature, Heat, and Expansion" and Chapter 15, "Heat Transfer" in Conceptual Physics by Paul Hewitt.
2. Read the Temperature and Heat Information Sheet.
3. View the videotape "Temperature and Heat" (NUS Training Corporation) or the videotape "Plant Science - 3: Heat" (NUS Training Corporation).
4. Complete the Temperature and Heat Worksheet.

Evaluation/Checkout:

1. Submit the Temperature and Heat Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain change of state.
2. Describe how heat influences change of state.
3. Demonstrate the use of steam tables.

Instructional Objectives:

1. Define melting and boiling.
2. Define condensation and evaporation.
3. Differentiate between latent and sensible heat.
4. Explain the difference between boiling and evaporation.
5. Solve problems concerned with melting, boiling, evaporation and condensation.
6. Define saturated and superheated steam.
7. Calculate the amount of steam necessary to accomplish a task given a particular pressure.
8. Demonstrate the ability to use steam tables.

Learning Activities:

1. Read Chapter 16 "Change of State" in Conceptual Physics by Paul Hewitt.
2. Read the Change of State Information Sheet.
3. Read the information your instructor gives you on Steam Tables.
4. View the videotape "Water/Steam Properties" (NUS Training Corporation) and "The Steam Tables" (NUS Training Corporation).
5. Complete the Change of State Worksheet.

Evaluation/Checkout:

1. Submit the Change of State Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
1. Describe the purpose of hangers and supports in piping systems.
2. Demonstrate the ability to install/fabricate hanger and support setups.

Instructional Objectives:
1. Identify typical hangers, supports, and rod attachments.
2. Explain the function of typical hangers and supports.
3. Differentiate among hangers and supports in terms of their application.
4. Install masonry anchors properly.
5. Install a rod hanger.
6. Fabricate a bracket to given dimensions.

Learning Activities:
1. Read the Pipe Hangers and Supports Information Sheet.
2. Review the "Distance Between Supports Chart" and the formula for determining lengths of structural braces in Pipe Fitting and Piping Handbook, Chapter 15.
3. Examine the hangers and supports on display in your classroom.

Application Exercises:
1. Install masonry anchors properly.
2. Install a rod hanger.
3. Fabricate a bracket to given dimensions.

Evaluation/Checkout:
1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Differentiate between categories of pipe welding.
2. Identify pipe welding qualification positions.
3. Describe safety requirements for pipe welding.
4. Describe equipment required for pipe welding setup.
5. Demonstrate the ability to use welding setup equipment.

Instructional Objectives:

1. Match terms related to pipe welding orientation, safety, and equipment with their correct definitions.
2. Differentiate between basic categories of pipe welding.
3. Complete a list of characteristics of industrial pipe welding.
4. Solve problems concerning classifications for industrial pipe.
5. Complete statements concerning welding skills required for good pipe welding.
6. Differentiate between organizations that set pipe and pipe welding standards.
7. Identify AWS test positions for groove welds on pipe.
8. Complete statements concerning how pipe welders are qualified.
9. Identify true statements concerning general guidelines for pipe welding safety.
10. Complete statements concerning types of line-up clamps and their characteristics.
11. Select true statements concerning characteristics of pipe beveling machines.
12. Complete statements concerning jack stands and their uses.
13. Select true statements concerning center finders and their uses.
14. Differentiate between types of contour markers.
15. Solve a problem concerning wrap-arounds and their uses.
16. Complete statements concerning templates and their uses.
17. Complete statements concerning the use of two-hole pins and back-up rings.
18. Demonstrate the use of internal and external line-up clamps.
19. Demonstrate the use of center finders and contour markers.
20. Demonstrate the use of a wrap-around.
21. Demonstrate the use of two-hole pins.
22. Demonstrate the use of back-up rings.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet in Unit I "Pipe Welding Orientation, Safety, and Equipment" of "Shielded Metal Arc Pipe Welding."
2. Read Chapter 12 in Pipe Fitting and Piping Handbook.
3. Examine the various types of welded pipe and pipe welds on display in your classroom.
4. View the videotape on the Dearman System dealing with pipe fit-up tools for welding.
5. Observe as your instructor or a company representative demonstrates the procedure for using the Dearman System of tools for welding. Use the Dearman System Handbook as your guide.
6. Observe as your instructor or a company representative demonstrates the procedure for using the Contour Precision Layout and Measuring Tools from Jackson Products. Use the Contour Marker instruction booklet as your guide.

Application Exercises:

1. Demonstrate the use of internal and external line-up clamps.
2. Demonstrate the use of center finders and contour markers.
3. Demonstrate the use of a wrap-around.
4. Demonstrate the use of two-hole pins.
5. Demonstrate the use of back-up rings.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:
1. Discuss the use of pipe symbols in blueprint reading and layout for pipe welding.
2. Identify symbols for pipe and pipe fittings.
3. Describe the advantages of using isometric drawings for pipe welding blueprints.
4. Solve basic layout problems.
5. Construct templates for pipe welding applications.

Instructional Objectives:
1. Match terms related to blueprint reading and layout for pipe welding with their correct definitions.
2. Identify methods for presenting pipe on blueprints.
3. Match common piping symbols with their meanings.
4. Identify methods for dimensioning blueprints for pipe welding.
5. Identify symbols for common pipe fittings.
6. Match special welded fittings with their uses.
7. Identify statements concerning advantages of isometric drawings for pipe welding blueprints.
8. Identify statements concerning steps in solving trigonometric problems.
9. Arrange in order the steps in laying out angles on 90 degree long radius elbows.
10. Solve a problem using the 12-inch rule for finding angles with a steel square.
11. Complete a statement concerning pipe identification.
12. Complete a list of standard weld fittings.
13. Solve trigonometry problems for unknown sides and unknown angles.
14. Demonstrate the ability to develop a template for an orange-peel head on 2" pipe.
15. Demonstrate the ability to develop a template for a two-piece 90 degree turn.
16. Demonstrate the ability to develop a template for a 90 degree branch with pipes of equal size.
17. Demonstrate the ability to develop a template for a 45 degree branch connection.

Learning Activities:
1. Read and then discuss in-class sessions the Information Sheet in Unit II "Blueprint Reading and Layout for Pipe Welding" of Shielded Metal Arc Pipe Welding.
2. Attend an in class presentation by a layout specialist from a welding company.
3. Complete Assignment Sheet 1, "Solve Trigonometry Problems for Unknown Sides" in Unit II of Shielded Metal Arc Pipe Welding.
4. Complete Assignment Sheet 2, "Solve Trigonometry Problems for Unknown Angles" in Unit II of Shielded Metal Arc Pipe Welding.

5. Complete Job Sheet 1, "Develop a Template for an Orange-Peel Head on 2" Pipe" in Unit II of Shielded Metal Arc Pipe Welding.
6. Complete Job Sheet 2, "Develop a Template for a Two-Piece 90 Degree Turn" in Unit II of Shielded Metal Arc Pipe Welding.
7. Complete Job Sheet 3, "Develop a Template for a 90 Degree Branch with Pipes of Equal Size" in Unit II of Shielded Metal Arc Pipe Welding.
8. Complete Job Sheet 4, "Develop a Template for a 45 Degree Branch Connection" in Unit II of Shielded Metal Arc Pipe Welding.

Evaluation/Checkout:

1. Submit Assignment Sheets 1 and 2.
2. Submit Job Sheets 1, 2, 3, and 4.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify proper electrodes for pipe welding.
2. Describe joint preparation, fit-up, alignment, and cleaning requirements for pipe welding.
3. Explain methods of nondestructive and destructive weld testing.
4. Demonstrate the ability to bevel and prepare pipe for welding.
5. Conduct destructive tests on welded pipe.
6. Weld to specifications V-groove joints in vertical up and vertical down positions.

Instructional Objectives:

1. Match terms related to pipe welding techniques and applications with their correct definitions.
2. Select true statements concerning guidelines for beginning pipe welders.
3. Solve problems concerning AWS electrode classifications for mild steel and alloy electrodes.
4. Complete statements concerning electrode selection for pipe welding.
5. Complete statements concerning joint preparation, fit-up and alignments for pipe welding.
6. Identify common methods of pipe alignment.
7. Complete statements concerning joint preparation for vertical down pipe welding.
8. Complete statements concerning special items in vertical down joint preparation.
9. Identify true statements concerning pass detail and sequence for vertical down pipe welding.
10. Complete statements concerning joint preparation for vertical up welding.
11. Complete statements concerning pass detail and sequence for vertical up pipe welding.
12. Select true statements concerning techniques for horizontal pipe welding.
13. Complete statements concerning cleaning requirements for all pipe welding.
14. Match common problems in pipe welding with their causes.
15. Complete a pipe welding troubleshooting chart.
16. Complete a list of ways to prevent pipe welds from cracking.
17. Solve problems concerning the concept of quartering.
18. Differentiate between methods of pipe inspection.
19. Demonstrate the ability to bevel and prepare pipe for welding.
20. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the horizontal position.
21. Demonstrate the ability to conduct root and face bend tests and a nick-break test on welded pipe.

22. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the vertical up position.
23. Demonstrate the ability to weld to specifications a V-groove butt joint on 6" schedule 40 pipe in the vertical down position.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet in Unit III "Pipe Welding Techniques and Applications" of Shielded Metal Arc Pipe Welding.
2. View the videotapes "Shielded Metal Arc Pipe Welding" (Miller Electric).
3. Complete Job Sheet 1, "Bevel and Prepare Pipe for Welding" in Unit III of Shielded Metal Arc Pipe Welding.
4. Complete Job Sheet 2, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Horizontal Position" in Unit III of Shielded Metal Arc Pipe Welding.
5. Complete Job Sheet 3, "Conduct Root and Face Bend Tests and a Nick-Break Test on Welded Pipe" in Unit III of Shielded Metal Arc Pipe Welding.
6. Complete Job Sheet 4, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Up Position" in Unit III of Shielded Metal Arc Pipe Welding.
7. Complete Job Sheet 5, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Up Position" in Unit III of Shielded Metal Arc Pipe Welding.
8. Complete Job Sheet 6, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Down Position" in Unit III of Shielded Metal Arc Pipe Welding.
9. Complete Job Sheet 7, "Weld to Specifications a V-Groove Butt Joint on 6" Schedule 40 Pipe in the Vertical Down Position" in Unit III of Shielded Metal Arc Pipe Welding.

Evaluation/Checkout:

1. Complete Job Sheets 1, 2, 3, 4, 5, 6, and 7.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the setup, use, and care of oxyacetylene welding-cutting equipment.
2. Demonstrate the setup, use, and care of shielded metal arc welding equipment.

Instructional Objectives:

1. Match terms related to cutting and welding with their correct definitions.
2. Complete a list of equipment required for oxyacetylene welding.
3. Identify the parts of a cutting torch.
4. Complete statements concerning basic safety rules for oxyacetylene cylinders and gases.
5. Match examples of poor cuts with their causes.
6. List causes of a backfire.
7. Complete statements concerning the results of a backfire.
8. Complete statements concerning the results of a flashback.
9. Arrange in order the steps to follow in case of a flashback.
10. Select factors that determine fusion weld quality.
11. List five properties of a good weld.
12. Select factors that determine tip size selection in welding.
13. Select factors that determine filler rod selection in welding.
14. State the purpose of the filler rod.
15. Identify four types of oxyacetylene fusion welding flames.
16. Select the proper tip size, acetylene pressure, and oxygen pressure for a given metal thickness.
17. Select the acceptable lens shade number for welding a given metal thickness.
18. Demonstrate personal protection when welding by wearing the proper safety clothing and equipment.
19. Assemble, inspect, light, adjust, extinguish, turn-off, and disassemble oxyacetylene welding-cutting equipment.
20. Setup shielded metal arc welding equipment selecting the proper electrodes, amperage, voltage, current, and polarity.
21. Make ninety degree cuts on mild steel and restart a cut using oxyacetylene welding equipment.
22. Make a bevel cut on mild steel using oxyacetylene welding equipment.
23. Make a straight and bevel cut on pipe using oxyacetylene welding equipment.
24. Lay beads on metal with and without a filler rod using oxyacetylene welding equipment.
25. Weld a butt joint in the flat position using oxyacetylene welding equipment.
26. Strike an arc and weld stringer and weave beads using shielded metal arc welding equipment.

27. Weld a single V-groove butt joint in the flat position using shielded metal arc welding equipment.
28. Make a tee joint with a fillet weld using shielded metal arc welding equipment.

Learning Activities:

1. Read and then discuss in class sessions the Information Sheet from Section E in Unit V-E "Oxyacetylene Cutting, Welding, and Brazing." of Air Conditioning and Refrigeration Fundamentals.
2. Read "Principles of Arc Welding" by Miller Electric.
3. View the videotape "Arc Welding Methods" (Miller Electric).
4. View the videotape series "Shielded Metal Arc Plate Welding - Part I" (Miller Electric).
5. Complete Job Sheet 1, "Setup Oxyacetylene Welding Equipment."
6. Complete Job Sheet 2, "Light, Adjust, and Shut Off Oxyacetylene Welding Equipment."
7. Complete Job Sheet 3, "Make 90 Degree Cuts on Mild Steel and Restart a Cut."
8. Complete Job Sheet 4, "Make a Bevel Cut on Mild Steel."
9. Complete Job Sheet 5, "Make a Straight Cut on Pipe."
10. Complete Job Sheet 6, "Make a Bevel Cut on Pipe."
11. Complete Job Sheet 7, "Lay Beads on Gauge Metal Without a Filler Rod."
12. Complete Job Sheet 8, "Lay Beads on a Flat Plate With a Filler Rod."
13. Complete Job Sheet 9, "Weld a Butt Joint in the Flat Position."
14. Complete Job Sheet 10, "Weld Stringer and Weave Beads."
15. Complete Job Sheet 11, "Weld a Tee Joint."
16. Complete Job Sheet 12, "Weld a Single V-Grooved Butt Joint."

Evaluation/Checkout:

1. Complete Job Sheets 1-12 and have your instructor evaluate your performance. Practice welds will be compared to master welds.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the manner in which a force is transmitted through a confined fluid.
2. Explain the operation of transmitting energy in an efficient pneumatic system.
3. Distinguish among the various control devices used in a pneumatic system.

Instructional Objectives:

1. Define Pascal's law.
2. Define pressure.
3. Explain what a fluid power cylinder consists of.
4. Describe how a cylinder works.
5. Describe the operation of an intensifier.
6. Identify two pressure scales used to measure pressure in a fluid power system.
7. Explain how a plunger gauge and a bourdon tube gauge works.
8. Define what a gas is.
9. Define what heat energy is.
10. Explain what gas pressure is.
11. Describe the relationship between volume, temperature, and pressure in a pneumatic system.
12. Describe the operation of a positive displacement compressor.
13. List three causes of pneumatic system inefficiency.
14. Explain how flow rate is measured in a pneumatic system.
15. Explain how the term velocity is used in a pneumatic system.
16. Describe why pressure must be controlled in a pneumatic system.
17. Explain how a pressure switch works in a pneumatic system.
18. Explain how a safety relief valve works in a pneumatic system.
19. Explain how a pressure regulator works in a pneumatic system.
20. Describe the purpose of a double-acting cylinder and a directional control valve in a pneumatic system.
21. Describe how flow rate is controlled in a pneumatic system.
22. Identify pneumatic symbols.

Learning Activities:

1. Read Chapters 1,2,3, and 4 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 2,3,and 4.
3. View the videotapes "Force Transmission Through a Fluid," "Energy Transmission Using a Pneumatic System," and "Control of Pneumatic Energy" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as provided by your instructor.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the operation of and be able to identify the compressors of typical pneumatic systems.
2. Explain the purpose of aftercoolers, driers, and receivers in a pneumatic system.
3. Describe typical piping systems for a pneumatic system.
4. Demonstrate the ability to inspect a pneumatic system for leaks.
5. Demonstrate the ability to install a drain trap in a pneumatic system.

Instructional Objectives:

1. List two basic groups of air compressors and explain their operation.
2. Identify types of positive displacement compressors.
3. Explain the operation of positive displacement compressors.
4. Identify types of centrifugal compressors.
5. Explain the operation of centrifugal compressors.
6. State the purpose of a multi-stage compressor.
7. Describe ways of unloading or controlling the output of a compressor.
8. Explain why ventilation is important for an air-cooled compressor.
9. List three factors to consider when installing a compressor.
10. State the purpose of an aftercooler.
11. Identify four methods that provide drier air to a pneumatic system.
12. Explain the purpose of a receiver tank.
13. Describe three types of piping systems used in pneumatic systems.
14. List six factors that should be considered when laying out a pneumatic circuit.
15. List methods of leak detection in a pneumatic system.
16. Check a pneumatic system for leaks.
17. Install a drain trap in a pneumatic system.

Learning Activities:

1. Read Chapters 5 and 6 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 5 and 6.
3. Read "Drainage of Water and Oil from Compressed Air" (Bulletin 251-B) from Armstrong Machine Works.
4. View the videotapes "Compressors" and "Aftercoolers, Driers, Receivers - Air Distribution System" (Parker Hannifin).
5. Participate in sessions on a pneumatics trainer as provided by your instructor.

Application Exercises:

1. Check a pneumatic system for leaks.
2. Install a drain trap in a pneumatic system.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify check valves, cylinders, and motors and describe their basic operation and typical application.
2. Demonstrate the ability to repair/install a pneumatic cylinder.

Instructional Objectives:

1. Describe how a check valve works.
2. List the components of a pneumatic cylinder.
3. List types of seals used on a pneumatic cylinder.
4. Identify where seals are located on a pneumatic cylinder.
5. State the purpose of a stroke adjuster.
6. List six cylinder mounting styles.
7. List six types of pneumatic cylinders.
8. Explain how to size a cylinder.
9. Solve cylinder sizing problems.
10. Repair/install a pneumatic cylinder.
11. Explain the purpose of a stop tube.
12. Explain how a stop tube is selected.
13. Calculate stop tube length.
14. List three reasons why a cylinder may buckle.
15. Explain the purpose of cushions for a pneumatic cylinder.
16. Determine if a cylinder will be able to cushion a particular load.
17. Explain what determines the flow rate into a cylinder.
18. Calculate the flow rate for a pneumatic cylinder.
19. List four types of pneumatic motors.
20. Identify applications for various types of pneumatic motors.

Learning Activities:

1. Read Chapter 7 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapter 7.
3. View the videotape "Check Valve, Cylinders and Motors" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as provided by your instructor.

Application Exercises:

1. Repair/install a pneumatic cylinder.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify pneumatic directional control valves.
2. Describe the operation of pneumatic directional control valves.
3. Explain the basic function, operation, and placement of flow control valves, silencers, and quick exhaust valves.
4. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve in a pneumatic system.

Instructional Objectives:

1. Identify three ways directional valves can function.
2. Explain the function of a two-way directional valve.
3. Explain the function of a three-way directional valve.
4. Explain the function of a four-way directional valve.
5. Describe how and why a three-way directional valve can replace a four-way directional valve.
6. List four ways directional valves can be operated.
7. Explain what a spring offset valve is.
8. Explain what normally opened and normally closed valves are.
9. Describe the purpose of detents for directional valves.
10. List three center conditions of pneumatic directional valves.
11. Name two ways directional control valves are sealed.
12. Identify four basic types of shear action valves.
13. Describe how the four basic types of shear action valves seal.
14. Distinguish between a poppet valve and a shear action valve.
15. Size pneumatic directional controls by using the CV formula.
16. Disassemble, inspect, and reassemble a directional control valve.
17. List four factors that affect flow through an orifice.
18. List three types of variable orifices.
19. Explain the term "meter out" control.
20. Name the most common type of flow control valve found in a pneumatic system.
21. Explain what the term "jump" means for pneumatic controls.
22. Explain the purpose of a quick exhaust valve.
23. Explain the purpose of a silencer in a pneumatic system.

Learning Activities:

1. Read Chapters 8 and 9 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 8 and 9.
3. View the videotapes "Directional Control Valves" and "Flow Control Valves, Silencers, and Quick Exhausts" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as supplied by your instructor.

Application Exercises:

1. Disassemble, inspect and reassemble a directional control valve in a pneumatic system.

Evaluation/Checkout:

1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the function of regulators, excess flow valves, boosters, and sequence valves that are found in a typical pneumatic system.
2. Describe the components of air preparation, their operation, and the sources of contamination for a pneumatic system.
3. Demonstrate the ability to repair/install a pressure regulator in a pneumatic system.
4. Demonstrate the ability to repair/install an air line filter in a pneumatic system.
5. Demonstrate the ability to repair/install a lubricator in a pneumatic system.
6. Demonstrate the ability to repair/install a FRL unit in a pneumatic system.

Instructional Objectives:

1. Describe the function of a sequence valve.
2. Describe the function of a pressure regulator.
3. List two applications of a pressure regulator in a pneumatic system.
4. Distinguish between a venting and non-venting type pressure regulator.
5. Distinguish between a piston type and diaphragm type regulator.
6. List two advantages of a pilot controlled regulator over a standard regulator.
7. Calculate the correct size regulator for a particular pneumatic circuit.
8. Repair/install a pressure regulator in a pneumatic system.
9. Describe when dual regulation is used in a pneumatic system.
10. Explain the purpose of a booster in a pneumatic system.
11. Name two types of boosters.
12. Explain the purpose of an excess flow valve in a pneumatic system.
13. Calculate yearly cost savings by comparing pneumatic circuits.
14. Describe three sources of contaminants in a pneumatic system.
15. List three contaminant types found in a pneumatic system.
16. Explain how a micrometer seal is used to measure contaminants.
17. Describe the function of an air line filter.
18. Identify the parts of an air line filter.
19. Distinguish between depth type and edge type filter elements.
20. Explain what a nominal rating is for a filter.
21. Repair/install an air line filter in a pneumatic system.
22. Explain the purpose of an oil removal filter.
23. Describe how a filter is drained.
24. List three steps in selecting a filter.
25. Explain the purpose of air line lubrication in a pneumatic system.
26. List three types of air line lubricators.
27. Identify three reasons for having a lubricator in a pneumatic system.

28. Repair/install a lubricator in a pneumatic system.
29. Explain what a FRL unit is.
30. Repair/install a FRL unit in a pneumatic system.

Learning Activities:
1. Read Chapters 10 and 11 in Industrial Pneumatic Technology.
2. Complete the Exercises at the end of Chapters 10 and 11.
3. View the videotapes "Regulators, Excess Flow Valves, Boosters and Sequence Valves" and "Air Preparation" (Parker Hannifin).
4. Participate in sessions on a pneumatics trainer as supplied by your instructor.

Application Exercises:
1. Repair/install a pressure regulator in a pneumatic system.
2. Repair/install an air line filter in a pneumatic system.
3. Repair/install a lubricator in a pneumatic system.
4. Repair/install a FRL unit in a pneumatic system.

Evaluation/Checkout:
1. Submit your answers to the Exercises.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify and use basic drafting tools.
2. Draw freehand sketches.
3. Demonstrate basic drafting techniques.
4. Create multi-view drawings.

Instructional Objectives:

1. Choose and effectively use the correct drawing instruments.
2. Scale prints accurately with the architect's scale.
3. Identify the types of freehand drawings.
4. Draw freehand sketches of horizontal, vertical, and angular lines.
5. Draw freehand sketches of angles, arcs, and circles.
6. Draw multi-view (top, front, right side) sketches of objects.
7. Draw isometric circles and arcs.
8. Describe the different types of drawings in a pipe drafting project.
9. Identify the types of lines used in pipe drafting.
10. Trace runs of pipe on drawings.

Learning Activities:

1. Participate in class lectures and discussions on drafting instruments and freehand sketching.
2. Read pp. 8-29 in Orthographic Projection Simplified.
3. Complete the Problems on pp. 30-65 in Orthographic Projection Simplified as assigned by your instructor.
4. Read pp. 66-67 in Orthographic Projection Simplified.
5. Complete the Problems on pp. 68-81 in Orthographic Projection Simplified as assigned by your instructor.
6. Read p. 82 and complete the Problems on pp. 83-93 in Orthographic Projection Simplified.
7. Read Chapter 1 in Process Pipe Drafting.
8. Complete the Review Questions (1-20) at the end of Chapter 1 in Process Pipe Drafting.
9. Complete Assignment Sheet 1, "Basic Drafting Techniques."
10. Complete Assignment Sheet 2, "Basic Freehand Sketching."
11. View the videotape "Reading Diagrams" (NUS Training Corporation).

Application Exercises:

1. Trace runs of pipe on drawings.
2. Sketch simple orthographic drawings.
3. Measure dimensions from blueprints using an architect's scale.

Evaluation/Checkout:

1. Submit the assigned Problems from Orthographic Projection Simplified.
2. Submit the Review Questions from Process Pipe Drafting.
3. Submit Assignment Sheets 1 and 2.
4. Submit your checklist of application exercises.

Competency:

1. Describe pipe and pipe fittings in terms of pipe drafting.
2. Explain how valves and measurement instruments are shown in pipe drafting.
3. Explain how pumps, tanks and piping equipment are shown in pipe drafting.
4. Create multi-view drawings of pipe and fitting assemblies.
5. Interpret drawings of pipe and fitting assemblies.

Instructional Objectives:

1. Describe two methods of classifying pipe thickness.
2. Identify various types of pipe fittings.
3. Sketch the symbols that are used to stand for pipe fittings.
4. Sketch multi-views of double line and single line pipe fittings.
5. Use fitting charts to obtain welding fittings' and welding flanges' dimensions.
6. Sketch multi-views of simple piping assemblies.
7. Name three functions of valves.
8. Sketch the symbols that are used to stand for valves and measurement instruments.
9. Sketch in missing valves and instruments in flow diagrams.
10. Use manufacturer's valve specifications to find dimensions.
11. Convert an isometric pipe assembly to a single line and double line sketch.
12. Trace runs of pipe and identify valves, fittings, pumps, and tanks on simple piping drawings.
13. Use specifications to obtain information from drawings.
14. Sketch the symbols that are used to stand for pumps, tanks, and piping equipment.
15. Describe the information that is found on the bill of material.
16. Calculate the needed dimensions and elevations in drawings.

Learning Activities:

1. Read Chapters 2, 3, and 4 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 2: 1-19, Problems 2-1, 2-2, 2-5, and 2-6; Chapter 3: 1-14, Problems 3-1, 3-2, 3-3, 3-4, and 3-7; and Chapter 4: 1-11, Problems 4-1, 4-4, and 4-5.
3. View the videotape "Reading Piping Drawings" (Marshall Maintenance Productions).

Application Exercises:

1. Trace runs of pipe and identify valves, fittings, pumps, and tanks.
2. Use specifications to obtain information from drawings.
3. Calculate the needed dimensions and elevations in drawings.

Evaluation/Checkout:

1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Competency:

1. Describe the purpose of a flow diagram.
2. Explain the parts of a flow diagram.
3. Describe the purpose of elevation drawings and section drawings.
4. Describe the components of a piping plan.
5. Interpret the information on flow diagrams, elevation drawings, section drawings, and piping plans.

Instructional Objectives:

1. Identify the function of a flow diagram.
2. List the components of a flow diagram.
3. Identify the symbols that are used in drawing a flow diagram.
4. Sketch the symbols that are used in drawing a flow diagram.
5. Explain what a pipe specification symbol is.
6. Sketch the equipment, valves, and instruments on a flow diagram.
7. List the components of a piping plan.
8. Explain how dimensioning is done on a piping plan.
9. Describe how project specifications are used on a piping plan.
10. Identify the purposes of elevation and section drawing.
11. Explain how dimensioning is done on elevation and section drawings.
12. Calculate elevations of items found on piping drawings.
13. Sketch elevation views of pipe and fitting assemblies.
14. Describe how notes, abbreviations, and revisions are used on pipe drawings.
15. Identify abbreviations used on piping drawings.
16. Interpret notes on piping drawings.
17. Use flow diagrams, elevations drawings, and section cuts to trace given runs of pipe.
18. Use flow diagrams, elevation drawings, and sections cuts to interpret information about given runs of pipe.

Learning Activities:

1. Read Chapters 5, 6, and 7 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 5: 1-11, Problem 5-2; Chapter 4: Problem 4-3; Chapter 6: 1-12, Problems 6-2 and 6-4; and Chapter 7: 1-18, Problems 7-1 and 7-2.

Application Exercises:

1. Use flow diagrams, elevation drawings, and section cuts to trace given runs of pipe.
2. Use flow diagrams, elevation drawings, and section cuts to interpret information about given runs of pipe.

Evaluation/Checkout:

1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Competency:

1. Define what an isometric drawing is.
2. Describe the layout of an isometric drawing.
3. Sketch isometric piping and fittings.
4. Explain the purpose and layout of a spool drawing.
5. Read a specifications book and develop a material list for a specific job.

Instructional Objectives:

1. Identify the function of an isometric drawing.
2. Explain why it is always important to orient yourself with the north arrow in an isometric drawing.
3. Identify how symbols are oriented on isometric drawings.
4. Demonstrate the ability to do freehand isometric drawings.
5. Demonstrate the ability to dimension and letter freehand isometric drawings.
6. Interpret information found on isometric drawings.
7. Sketch an isometric drawing from an orthographic drawing.
8. Differentiate between isometric drawings and spool drawings.
9. Interpret information found on spool drawings.
10. Sketch a spool drawing from an isometric drawing.
11. Construct a bill of material for a spool drawing.
12. Use a specifications book and an isometric drawing and construct a material list for a specific job.

Learning Activities:

1. Read Chapter 8 and 9 in Process Pipe Drafting.
2. Complete the following Review Questions at the end of Chapter 8: 1-11, Problems 8-2, 8-4, and 8-5; and Chapter 9: 1-7, Problems 9-2, 9-3, 9-4, and 9-5.

Application Exercises:

1. Interpret information found on isometric drawings.
2. Interpret information found on spool drawings.
3. Use a specifications book and an isometric drawing and construct a material list for a specific job.

Evaluation/Checkout:

1. Submit the Review Questions and Problems from Process Pipe Drafting.
2. Submit your checklist of application exercises.

Competency:

1. Explain stress in relation to piping material.
2. Evaluate strength of piping material.
3. Interpret expansion/contraction effects.

Instructional Objectives:

1. Define tension stress, compression stress, and shearing stress.
2. Identify the properties of metals.
3. Define elasticity, strength, hardness, toughness, plasticity, ductility, malleability, brittleness, weldability, machinability, thermal conductivity, and corrosion resistance.
4. Define expansion and contraction.
5. Explain the coefficient of linear expansion.
6. Describe the function of expansion joints.
7. List types of expansion joints.

Learning Activities:

1. Read the Properties of Metals Information Sheet.
2. Read the Expansion/Contraction Information Sheet.
3. Complete the Properties of Metals Worksheet.

Evaluation/Checkout:

1. Submit the Properties of Metals Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe characteristics and applications of piping materials.
2. Describe types of joints and bonding techniques for piping materials.
3. Interpret flow properties of piping materials.

Instructional Objectives:

1. Identify the various materials from which pipe is made.
2. List applications of various materials.
3. List common methods for joining pipe.
4. State the advantages and disadvantages of threaded pipe systems.
5. State the advantages and disadvantages of welded pipe systems.
6. Explain how pipe is sized.
7. Identify common fittings used on pipe systems.
8. Identify common flanges used on pipe systems.
9. Use a flow conversion chart.

Learning Activities:

1. Read Chapters 1,2,3,4, and 13 in Pipe Fitting and Piping Handbook.
2. Complete the Piping Materials Worksheet.
3. Attend a presentation by a manufacturer's representative on fiberglass reinforced piping.

Evaluation/Checkout:

1. Submit the Properties of Materials Worksheet.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe bends, linear expansion of piping, volume of tanks, and offsets.
2. Fabricate piping offsets.

Instructional Objectives:

1. Review square root, the Pythagorean Theorem, and the six trigonometric functions.
2. Solve pipe bend problems.
3. Solve linear expansion of piping problems.
4. Solve volume of tank problems.
5. Solve piping offset problems.
6. Fabricate a simple offset.
7. Fabricate a two-pipe equal spread offset.
8. Fabricate a rolling offset.

Learning Activities:

1. Read The Pipefitter's and Pipe Welders's Handbook by Frankland and complete Worksheets 1-8. The pages of Frankland that should be read are listed on the Worksheets.
2. Read Chapters 8 and 9 in Pipe Fitting and Piping Handbook.

Application Exercises:

1. Fabricate a simple offset.
2. Fabricate a two-pipe equal spread offset.
3. Fabricate a rolling offset.

Evaluation/Checkout:

1. Submit Worksheets 1-8.
2. Submit your checklist of application exercises.

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Competency:

1. Perform calculations necessary to solve pipe layout and fabrication problems dealing with pipe welding layouts including miter cuts, cut lines on large pipe, tees, saddles, laterals, and elbows.
2. Use clamps and aligning devices employed in the trade.
3. Fabricate miters, tees, saddles, laterals, and elbows.

Instructional Objectives:

1. Identify pipe welding layout techniques.
2. Identify the various types of clamps and aligning devices used in the trade.
3. Use clamps to align pipe.
4. Use a level to align pipe.
5. Use a hi-lo gauge to determine alignment.
6. Use a two-hole leveler on a flange.
7. Square a flange.
8. Use a pipe flange aligner.
9. Solve miter cut problems.
10. Lay out miter cut problems.
11. Lay out and cut miters of 11 1/4, 15, 22 1/2, and 45 degrees.
12. Fabricate 2-, 3-, 4-, and 5-piece mitered elbows.
13. Solve saddle problems.
14. Layout, cut, and align saddles.
15. Solve problems dealing with tees, laterals, and Y fittings.
16. Fabricate tees, laterals, and Y fittings.
17. Use a contour marker to lay out elbows, laterals, tees, and saddles.

Learning Activities:

1. Read the Pipefitter's and Pipe Welder's Handbook by Frankland and complete Worksheets 1-6. The pages of Frankland that should be read are listed on the Worksheets.
2. Read Chapters 7 and 10 in Pipe Fitting and Piping Handbook.
3. Use Ordinates for 1000 Pipe Intersections to figure ordinates.
4. Observe as your instructor or a company representative demonstrates the procedure for using the Dearman System of pipe fit-up tools. Use the Dearman System Handbook and videotape as your guide.
5. Observe as your instructor or a company representative demonstrates the procedure for using the Contour Precision Layout and Measuring Tools from Jackson Products. Use the Contour Marker instruction booklet as your guide.

Application Exercises:

1. Demonstrate the use of internal and external line-up clamps.
2. Use a level to align pipe.
3. Demonstrate the use of a hi-lo gauge.
4. Demonstrate the use of a two-hole leveler.
5. Demonstrate how to square a flange and use a pipe flange aligner.
6. Demonstrate the use of a wrap-around.
7. Demonstrate the use of center finders.
8. Lay out ordinates on pipe.
9. Lay out and cut miters of 11 1/4, 15, 22 1/2, and 45 degrees.
10. Fabricate 2-, 3-, 4-, and 5-piece mitered elbows.
11. Lay out, cut, and align saddles.
12. Fabricate tees, laterals, and Y fittings.
13. Demonstrate the use of a contour marker to lay out elbows, laterals, and saddles.

Evaluation/Checklist:

1. Submit Worksheets 1-6.
2. Submit your checklist of application exercises.

Competency:

1. Describe the types of and operation of watertube and firetube boilers.
2. Explain the four separate systems that must function in order for a steam boiler to operate.

Instructional Objectives:

1. Describe the construction of the various high pressure boilers.
2. State ASME code concerning the difference between high pressure and low pressure boilers.
3. Identify the four separate systems of a steam boiler.
4. Explain the purpose of each of the four systems of a steam boiler.
5. Differentiate between the components of each of the four systems of a steam boiler.
6. Explain the function of the components of each of the four systems of a steam boiler.
7. Identify safety practices to be used when working with boilers and steam.
8. Draw a simple sketch of a steam system.
9. Draw a simple sketch of a feedwater system.

Learning Activities:

1. Read the Physics Review Information Sheet.
2. Read the Steam and Heat Information Sheet.
3. Read Chapters 1 and 3 and pp. 192-196 in High Pressure Boilers.
4. Read the Firetube Type Boilers Information Sheet.
5. Read the Watertube Type Boilers Information Sheet.
6. View the videotapes "Boiler Fundamentals" and "Basic Boiler Systems" (NUS Training Corporation).
7. Complete Assignment Sheet 1, "Sketch a Steam and Feedwater System."
8. Complete Assignment Sheet 2, "Inspect a Watertube Boiler."
9. Complete Tech Check 1 and Tech Check 3 in High Pressure Boilers.
10. Complete the Boiler Worksheet.

Evaluation/Checkout:

1. Submit Assignment Sheets 1 and 2.
2. Submit Tech Check 1 and 2.
3. Submit the Boiler Worksheet.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the purpose of the steam boiler fittings that are required to operate the boiler safely and efficiently.
2. Describe the steam boiler accessories that are necessary for its safe and efficient operation.
3. Demonstrate the ability to install steam boiler fittings and accessories.

Instructional Objectives:

1. Describe the purpose and operation of safety valves.
2. Explain the reasons a water column is used on a steam boiler.
3. Describe the functions the gauge glass, try cocks, and alarm whistles have on a steam boiler.
4. Identify the types of pressure gauges used on a steam boiler.
5. List the reasons boiler vents and steam separators are used on a steam boiler.
6. Explain the function of superheaters, economizers, and air heaters in a steam system.
7. List the purpose of a sootblower.
8. Describe the proper valve type to use for given boiler piping situations.
9. Detail the proper installation of a safety valve, water column, and pressure gauge on a steam boiler system.
10. Install a safety valve on a steam boiler system.
11. Install a water column on a steam boiler system.
12. Install a stop valve on a steam boiler system.
13. Install a blowdown valve on a steam boiler system.
14. Install a swing check valve in the feedwater line of a steam boiler system.
15. Differentiate between blowdown and flash tanks.
16. Describe the components of the heat recovery system for a steam boiler.

Learning Activities:

1. Read Chapter 2 in High Pressure Boilers.
2. Read pp. 495-518 in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Boiler Fittings" - Lecture 4 in the Boiler Fireman's Course.
3. Read the Heat Recovery Systems Information Sheet.
4. Read "Piping Pointers" and "Choosing the Right Valve" from Crane Company.
5. View the videotape "Boiler Operation, Waterside" (Marshall Maintenance).
6. Complete Tech Check 2 in High Pressure Boilers.
7. Complete the Steam Boiler Fittings and Accessories Worksheet.

Application Exercises:

1. Install a safety valve on a steam boiler system.
2. Install a water column on a steam boiler system.
3. Install a stop valve on a steam boiler system.
4. Install a blowdown valve on a steam boiler system.
5. Install a swing check valve in the feedwater line of a steam boiler system.

Evaluation/Checkout:

1. Submit the Tech Check 2.
2. Submit the Steam Boiler Fittings and Accessories Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the types of and purposes for the steam and water devices which are necessary for the boiler's efficient operation.
2. Identify the instruments that are used to control and measure boiler operation.
3. Explain the function of the auxiliary equipment which is part of the steam power plant operation.
4. Demonstrate the ability to install feed water devices.

Instructional Objectives:

1. Explain the operation of feedwater heaters and feedwater pumps.
2. Identify the reasons condensate tanks with pumps are used.
3. Diagram the equipment on a feedwater line.
4. Describe the different types of feedwater regulators.
5. Explain the function of desuperheaters and pressure-reducing stations.
6. Describe the operation of combustion controls.
7. Identify temperature measurement devices used in boiler operation.
8. Identify pressure measurement devices used in boiler operation.
9. Identify flow and level measurement devices used in boiler operation
10. Identify the feedwater controls used in boiler operation.
11. Identify steam temperature control methods used in boiler operation.
12. Describe the function of condensers, feedwater heaters, deaerators, evaporators, and cooling towers for steam power plant operation.
13. Diagram the components of a simple steam plant.
14. Install a feedwater pump.
15. Install a feedwater regulator.

Learning Activities:

1. Read Chapters 4, 8 and 9 in High Pressure Boilers.
2. Read the Boilers - Instruments and Controls Information Sheet.
3. Read the Steam Plant Auxiliaries Information Sheet.
4. Read the Bulletin "Fluid Control Valves" from Watts Regulator Company.
5. Inspect the measuring instruments and controls on display in your classroom.
6. View the videotapes "Heat Exchangers and Operation of Plant Auxiliaries," "Condensate and Feedwater System," and "Instrumentation and Control - 1: Process Measurement" (NUS Training Corporation).
7. Complete Tech Check 4, Tech Check 8, and Tech Check 9.
8. Complete the Instruments and Auxiliaries Worksheet.
9. Complete Assignment Sheet 1, "Diagram a Feedwater Line."
10. Complete Assignment Sheet 2, "Diagram a Steam Plant."

Application Exercises:

1. Install a feedwater regulator.
2. Install a feedwater pump.

Evaluation/Checkout:

1. Submit Tech Check 4 and Tech Check 9.
2. Submit Assignment Sheets 1 and 2.
3. Submit the Instruments and Auxiliaries Worksheet.
4. Submit your checklist of application exercises.
5. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain how steam heating systems work.
2. Describe the various types of steam heating systems.
3. Describe the function of the fittings and accessories used on a steam heating system.
4. Repair and maintain steam heating systems.

Instructional Objectives:

1. Differentiate between high pressure and low pressure steam heating systems.
2. Explain the use of steam tables and define the measurements that compose the tables.
3. Classify and describe steam heating systems according to the pressure or vacuum conditions.
4. Classify and describe steam heating systems according to the method of condensation flow to the boiler.
5. Classify and describe steam heating systems according to the piping arrangement.
6. Classify and describe steam heating systems according to the type of piping circuit.
7. Classify and describe steam heating systems according to the location of condensation return.
8. Identify the control components that are used to regulate steam boilers and provide safe and efficient operation.
9. Explain the main considerations in the design and installation of steam and condensate piping connections.
10. Troubleshoot a steam heating system, describing in detail, symptoms, their probable causes and corresponding remedies.
11. Describe five types of expansion joints.
12. Explain the purpose of pressure reducing valves.
13. Describe the operation of pressure reducing valves.
14. Draw a single line sketch of a pressure reducing valve installation.
15. Draw a simple sketch of a two-pipe, gravity, steam heating system.
16. Draw a simple sketch of a two-pipe, high pressure, steam heating system.
17. Draw a simple sketch of a Hartford return connection.
18. Install a pressure reducing valve.
19. Install a boiler water feeder on a low water cut-off.
20. Repair/replace a gate valve on a steam heating system.
21. Construct a Hartford return connection for a steam heating system.
22. Repair/maintain an expansion joint.

Learning Activities:

1. Read Chapter 8, "Steam Heating Systems," and pp. 469-519 in Chapter 15, "Boiler and Boiler Fittings," in Heating, Ventilating, and Air Conditioning Library - Volume I or read "Heating Boilers" - Lecture 11, and "Heating Accessories and Systems" - Lecture 12 in the Boiler Fireman's Course and read "Steam Heating" - Lecture 9 in Building Systems Technician - Course 2.
2. Read the "Service Guide" (Bulletin SL-SG) from McDonnell and Miller on boiler feeder cut-offs.
3. Read "Basic Controls for Low Pressure Steam Boilers" (Bulletin SL-BCS) from McDonnell and Miller.
4. Read "Thermostatic Temperature Regulators and Tempering Devices" (Bulletin TR-987) from Hoffman Fluid Technology Division/ITT Corporation.
5. Read pp. 1-7 in "Steam Conservation Guidelines for Condensate Drainage" (M101) from Armstrong Machine Works.
6. Read "Pressure Reducing Valves" (AY-110-A) from Armstrong Machine Works.
7. Read "Pressure Reducing Valves" (Bulletin PRV-385) from Hoffman Fluid Technology Division/ITT Corporation.
8. Read "Steam Pressure Regulators" (F-127-4) from Watts Regulator Company.
9. Read the Expansion Joints Information Sheet.
10. View the videotapes "Let's Talk PRV's" and "Guidelines for Steam System Efficiency" (Armstrong Machine Works).
11. Complete Assignment Sheet 1, "Diagram a Pressure Reducing Valve Installation."
12. Complete Assignment Sheet 2, "Diagram a Two-Pipe, Gravity, Steam Heating System."
13. Complete Assignment Sheet 3, "Diagram a Hartford Return Connection."
14. Complete the Steam Heating Systems Worksheet.

Application Exercises:

1. Install a pressure reducing valve.
2. Install a boiler water feeder or a low water cut-off device.
3. Repair/replace a gate valve on a steam heating system.
4. Construct a Hartford return connection for a steam heating system.
5. Repair/maintain an expansion joint.
6. Troubleshoot a steam heating system, describing in detail, symptoms, their probable causes and corresponding remedies.

Evaluation Checkout:

1. Submit Assignment Sheets 1, 2, and 3.
2. Submit the Steam Heating Systems Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Define steam trapping terminology.
2. Identify applications for steam traps including location, installation and sizing.
3. Demonstrate the ability to repair and install steam traps.

Instructional Objectives:

1. Define flash steam.
2. Define condensate.
3. Describe how the heat of steam is utilized.
4. Explain why it is necessary to remove condensate, air, and CO from a steam system.
5. Explain the purpose and function of steam traps.
6. List the advantages and disadvantages of float and thermostatic traps.
7. List the advantages and disadvantages of thermostatic bellows type traps.
8. List the advantages and disadvantages of thermostatic bimetal traps.
9. List the advantages and disadvantages of disc traps.
10. List the advantages and disadvantages of orifice traps.
11. List the advantages and disadvantages of bucket traps.
12. Draw and explain the proper piping of steam trap installation that will avoid flow and expansion problems.
13. Calculate trap sizing and safety load factors.
14. Explain the purpose of pipe line strainers.
15. Describe the function of rotary joints and syphons.
16. Repair and install a mechanical trap.
17. Repair and install a thermostatic trap.
18. Repair and install a thermodynamic trap.

Learning Activities:

1. Read "Engineering Data Manual-Steam Traps" (Bulletin STD-787) from Hoffman Fluid Handling Division/ITT Corporation.
2. Read "Steam Conservation Guidelines for Condensate Drainage" (M101) from Armstrong Machine Works.
3. Read "Inverted Bucket Traps" (Bulletin IBT-287) from Hoffman Fluid Handling Division/ITT Corporation.
4. Read the Information Sheet "Trapping Superheated Steam Mains" from Armstrong Machine Works.
5. Read the article "Strainers Must Be Correct Type, Size to Properly Protect Fluid Handling Equipment" from Pulp and Paper Buyers Guide, 1983.
6. Read the article "Principles of Steam Trap Operation...how four basic types maintain steam system efficiency" from Plant Engineering, 1981.
7. Read the Information Sheet "Flash Steam" (Bulletin No. 201) from Armstrong Machine Works.

8. View the videotapes, "The Armstrong Differential Condensate Controller," "Guidelines for Steam Trap Troubleshooting and Testing," "Guidelines for Steam Trap Repair" (Armstrong Machine Works) and "Rotary Joints - Installation and Maintenance" (Marshall Maintenance Productions).
9. Complete Assignment 1, "Diagram a Trap Installation for a Rotary Dryer."
10. Complete Assignment 2, "Diagram a Trap Installation for a Flash Tank."
11. Complete Assignment 3, "Diagram a Trap Installation for a Heat Exchanger."
12. Complete Assignment 4, "Diagram a Trap Installation for a Jacketed Kettle."
13. Complete Assignment 5, "Diagram a Trap Installation for a Process Air Heater."
14. Complete Assignment 6, "Diagram a Trap Installation for a Trap Draining to Gravity Return Line."
15. Complete the Steam Trap Worksheet.

Application Exercises:
1. Repair and install a mechanical trap.
2. Repair and install a thermostatic trap.
3. Repair and install a thermodynamic trap.
4. Calculate a trap sizing problem.

Evaluation/Checkout:
1. Submit Assignment Sheets 1, 2, 3, 4, 5, and 6.
2. Submit the Steam Trap Worksheet.
3. Submit your checklist of application exercises.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Describe the basic thermodynamics of refrigeration.
2. Define and identify components of the basic mechanical refrigeration cycle.
3. Identify basic components of an air conditioning system.

Instructional Objectives:

1. Define heat, temperature, and BTU.
2. Explain the difference between heat and temperature.
3. Define sensible, specific, and latent heat.
4. Describe states of conditioned air.
5. Distinguish between compression refrigeration components and absorption refrigeration components.
6. Identify types of compressors, evaporators, and condensers.
7. Describe types of metering devices commonly in use.
8. Label the state the refrigerant is in at various points in the refrigeration system.
9. Illustrate a basic refrigeration system.

Learning Activities:

1. Read "The Refrigeration Cycle" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
2. Read "Refrigeration System Components" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
3. Read "Refrigeration Compressors" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
4. Discuss in class sessions the Information Sheet from Section A - Unit I "History and Development" from Air Conditioning and Refrigeration Fundamentals.
5. Discuss in class sessions the Information Sheet from Section F - Unit I "Basic Mechanical Refrigeration" from Air Conditioning and Refrigeration Fundamentals.
6. View the videotape "Refrigeration Systems 1&2" (NUS Training Corporation) or "Introduction to Air Conditioning and Refrigeration" (Industrial Training Corporation).
7. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.
8. Complete Assignment Sheet 1, "Draw a Basic Refrigeration System" in Section F - Unit I from Air Conditioning and Refrigeration Fundamentals.

Evaluation/Checkout:

1. Submit Assignment Sheet 1.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Identify safe practices associated with refrigeration and air conditioning systems.
2. Identify special tools used on air conditioning and refrigeration equipment.

Instructional Objectives:

1. Match terms related to refrigeration and air conditioning safety with their definitions.
2. Complete a list of electrical safety rules.
3. Identify true statements concerning refrigerant related safety rules.
4. List the four highly flammable gases used in the working on air conditioning and refrigeration systems.
5. Complete a list of safety rules for using the air-acetylene torch.
6. Identify statements concerning safety rules for charging or discharging fluorinated hydrocarbon refrigerants.
7. Complete statements concerning safety rules for pressurizing a refrigeration system.
8. Complete statements concerning safety rules for handling refrigerant cylinders.
9. Identify special tools used in air conditioning and refrigeration and their uses.
10. Identify components of the refrigeration gauge set.
11. Match components of the refrigeration gauge set with their uses.

Learning Activities:

1. Discuss in class sessions the Information Sheet from Section B - Unit II "Specific Safety" from Air Conditioning and Refrigeration Fundamentals.
2. Discuss in class sessions the Information Sheet from Section C - Unit II "Special Tools" from Air Conditioning and Refrigeration Fundamentals.
3. Examine the special tools used on air conditioning and refrigeration equipment on display in your classroom.

Evaluation/Checkout:

1. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Explain the purpose of common refrigeration system accessories.
2. Demonstrate the ability to install common refrigeration accessories.
3. Describe the purpose of a refrigerant in a refrigeration system.
4. Explain the relationship between temperature and pressure in a refrigeration system.
5. Demonstrate use of the vacuum steam table.
6. Demonstrate the ability to evacuate a refrigeration system.

Instructional Objectives:

1. Identify refrigerant system accessories.
2. Select purposes of refrigerant system accessories.
3. Distinguish between factors in selecting a liquid line filter drier and a suction line filter drier.
4. Distinguish between types of service valves.
5. Demonstrate the ability to install a filter drier with flare fittings.
6. Demonstrate the ability to install a filter drier with sweat fittings.
7. Install a liquid indicator with flare fittings.
8. Attach a gauge manifold set using a stem type service valve.
9. Install a line tap access valve.
10. Install an access core type service valve.
11. Match terms related to refrigerants with correct definitions.
12. Match types of refrigerants with their correct applications.
13. List three methods of leak detection.
14. Identify safety precautions for refrigerant handling.
15. Describe the procedure for obtaining refrigeration system pressures.
16. Demonstrate the ability to pressure check an air conditioning system.
17. Demonstrate the ability to fill a charging cylinder.
18. Compute temperature-pressure problems.
19. Identify reasons for evacuating a refrigeration system.
20. Select the effects of air and moisture in a refrigeration system.
21. Outline the effects of ambient temperature on proper evacuation.
22. Distinguish between low and high vacuum pumps.
23. Distinguish between types of vacuum indicators.
24. Demonstrate the ability to use the vacuum table.
25. Demonstrate the ability to evacuate a refrigeration system.

Learning Activities:

1. Read "Refrigeration Accessories and Controls" from the Trane Air Conditioning Clinic and complete the Quiz at the end of the booklet.
2. Read "The Refrigeration Cycle", pp. 7-16, from the Trane Air Conditioning Clinic.

3. Discuss in class sessions the Information Sheets from Section F - Units II, III, and IV, "Refrigerant System Accessories," "Refrigerants," and "Evacuation" from Air Conditioning and Refrigeration Fundamentals.
4. View the videotapes "Vapor Compression Cycle Designs and Refrigerants" and "Pump Down, Evacuation, and Charging" (Industrial Training Corporation).
5. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.
6. Attend a lecture/discussion by an industry representative.
7. Complete Assignment Sheet 1, "List Cylinder Color Codes" and Assignment Sheet 2, "Compute Temperature - Pressure Problems" in Section F - Unit III from Air Conditioning and Refrigeration Fundamentals.
8. Complete Assignment Sheet 1, "Use the Vacuum Table" in Section F - Unit IV from Air Conditioning and Refrigeration Fundamentals.

Application Exercises:
1. Install a filter-drier with flare fittings.
2. Install a filter-drier with sweat fittings.
3. Install a liquid indicator with flare fittings.
4. Attach a gauge manifold set using a stem type service value.
5. Install a line tap access valve.
6. Install an access core type service valve.
7. Pressure check an air conditioning system.
8. Fill a charging cylinder.
9. Evacuate a refrigeration system.

Evaluation/Checkout:
1. Submit Assignment Sheets.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Distinguish between different types of tubing and fittings used in air conditioning and refrigeration installation/maintenance.
2. Identify the proper size and type of tubing and fittings needed for particular air conditioning and refrigeration jobs.
3. Demonstrate the ability to flare, bend, and swage tubing.
4. Identify different piping materials and pipe fittings used in air conditioning and refrigeration installation/maintenance.

Instructional Objectives:

1. Match terms related to tubing with their definitions.
2. Distinguish between nominal size copper tubing applications and ACR copper tubing applications.
3. List applications of aluminum and steel tubing.
4. Identify tube and flexible refrigerant hose fittings.
5. Match terms related to tubing operations with their correct definitions.
6. Identify types of flaring blocks.
7. Demonstrate the ability to make a single flare with a compression type flaring block.
8. Demonstrate the ability to make a single flare with a generating type flaring block.
9. Demonstrate the ability to make a double flare.
10. Demonstrate the ability to make a swage joint.
11. Demonstrate the ability to make a 90 degree bend.
12. Demonstrate the ability to make a 180 degree bend.
13. Demonstrate the ability to make a 45 degree bend.
14. List four types of pipe used in air conditioning and refrigeration.
15. Match types of pipe with their applications in air conditioning and refrigeration.
16. Distinguish between different piping material and pipe fittings used in air conditioning and refrigeration.
17. Complete a list of the advantages and disadvantages of plastic pipe.
18. Arrange in the order the steps in cutting and threading iron pipe.
19. Arrange in order the steps necessary for installing P.V.C. pipe.
20. Determine the lengths of P.V.C. and fittings necessary to construct a condensate line.

Learning Activities:

1. Read "Refrigeration System Piping" from the *Trane Air Conditioning Clinic* and complete the Quiz at the end of the booklet.
2. Discuss in class sessions the Information Sheets from Section D - Units I, II, and III, "Tubing," "Tubing Operations," and "Pipe" from *Air Conditioning and Refrigeration Fundamentals*.
3. Examine the actual fittings, tubing, and pipe used on air conditioning and refrigeration jobs on display in your classroom.
4. Observe as your instructor demonstrates the procedure for cutting and threading pipe, cutting and gluing P.V.C., and the procedure for making a flexible plastic pipe connection.

5. Complete Assignment Sheet 1, "Read Fitting Sizes," and Assignment Sheet 3, "Determine Lengths of P.V.C. and Fittings Necessary to Construct a Condensate Line" in Section D - Unit III from Air Conditioning and Refrigeration Fundamentals.

Application Exercises:

1. Make a single flare with a compression type flaring block.
2. Make a single flare with a generating type flaring block.
3. Make a double flare.
4. Make a swage joint.
5. Make a 90 degree bend.
6. Make a 180 degree bend.
7. Make a 45 degree offset.

Evaluation/Checkout:

1. Submit Assignment Sheets 1 and 3.
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a swage joint.
3. Demonstrate the ability to silver braze swage joints and silver braze a copper to a steel joint.

Instructional Objectives:

1. Match terms related to soldering and welding equipment with their definitions.
2. Identify safety rules for using soldering and welding equipment.
3. Complete a list of statements concerning lighting, adjusting, and extinguishing the air-acetylene torch.
4. Arrange in order the steps for setting up the oxyacetylene torch.
5. Arrange in order the steps for lighting, adjusting, and extinguishing the oxyacetylene torch.
6. Demonstrate the ability to light and adjust the air-acetylene torch.
7. Demonstrate the ability to light and adjust the halide torch leak detector using propane.
8. Demonstrate the ability to light and adjust the halide torch leak detector using air-acetylene.
9. Demonstrate the ability to light and adjust the oxyacetylene torch.
10. Match terms related to soft soldering with their definitions.
11. Arrange in order the steps in making a solder joint.
12. Distinguish between types of flux for soft solder.
13. List four conditions for creating capillary actions of solders.
14. Demonstrate the ability to clean, flux, and solder a swage joint.
15. Demonstrate the ability to solder an inverted swage joint.
16. Demonstrate the ability to solder a horizontal swage joint.
17. Match terms related to silver brazing with their definitions.
18. Select true statements concerning guidelines for using silver solder flux.
19. Match different temperature ranges with their correct flux characteristics.
20. Arrange in order the steps in using the air-acetylene high temperature wraparound tip for silver brazing.
21. Demonstrate the ability to silver braze an upright swage joint.
22. Demonstrate the ability to silver braze an inverted swage joint.
23. Demonstrate the ability to silver braze a horizontal swage joint.
24. Demonstrate the ability to silver braze a copper to a steel joint.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section E - Units I, II, and III, "Soldering and Welding Equipment," "Soft Soldering," and "Silver Brazing" from Air Conditioning and Refrigeration Fundamentals.
2. Observe as your instructor demonstrates the proper use of soldering and welding equipment and demonstrates soft soldering and silver brazing on swage joints.

Application Exercises:

1. Light and adjust the air-acetylene torch.
2. Light and adjust the halide torch leak detector using propane.
3. Light and adjust the halide torch leak detector using air-acetylene.
4. Clean, flux, and solder a swage joint.
5. Solder an inverted swage joint.
6. Solder a horizontal swage joint.
7. Soft solder with the oxyacetylene torch.
8. Silver braze an upright swage joint.
9. Silver braze an inverted swage joint.
10. Silver braze a horizontal swage joint.
11. Silver braze a copper to a steel joint.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate the ability to pressurize a refrigeration system with dry nitrogen.
2. Demonstrate the ability to use soap bubbles, a halide torch, and an electronic leak detector to find a refrigerant leak.
3. Demonstrate the ability to vapor charge and liquid charge a refrigerant system.

Instructional Objectives:

1. Define terms related to pressurizing and leak testing.
2. Complete statements concerning safety rules for pressurizing a refrigeration system.
3. Identify steps for determining if a refrigerant leak exists.
4. Arrange in order the steps for pressurizing a refrigeration system.
5. Demonstrate the ability to leak check using soap bubbles.
6. Demonstrate the ability to leak check using a halide torch.
7. Demonstrate the ability to leak check using an electronic detector.
8. Demonstrate the ability to pressurize system with dry nitrogen and leak check the system.
9. Match terms related to charging with their definitions.
10. Complete statements concerning safety precautions for refrigerant handling.
11. Identify true statements concerning advantages and disadvantages of low side vapor charging.
12. List an advantage and disadvantage of high side liquid charging.
13. Demonstrate the ability to vapor charge using a charging cylinder.
14. Demonstrate the ability to vapor charge using a refrigerant cylinder.
15. Demonstrate the ability to liquid charge using a charging cylinder.
16. Demonstrate the ability to liquid charge using a refrigerant cylinder.

Learning Activities:

1. Discuss in class sessions the Information Sheets from Section G - Units I and II, "Pressurizing and Leak Testing," and "Charging" from Air Conditioning and Refrigeration Fundamentals.
2. Observe as your instructor demonstrates the proper techniques to use to pressurize, leak test, and charge a refrigeration system.
3. Read "The Refrigeration and Air Conditioning Troubleshooting Checklist."
4. View the videotape "Test and Maintenance Equipment" (Industrial Training Corporation).
5. Participate in sessions on an air conditioning and refrigeration trainer as provided by your instructor.

Application Exercises:

1. Leak check using soap bubbles.
2. Leak check using a halide torch.
3. Leak check using an electronic detector.
4. Pressurize system with dry nitrogen and leak check.
5. Vapor charge using a charging cylinder.
6. Vapor charge using a refrigerant cylinder.
7. Liquid charge using a charging cylinder.
8. Liquid charge using a refrigerant cylinder.

Evaluation/Checkout:

1. Submit your checklist of application exercises.
2. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Demonstrate basic safe practices associated with rigging.

Instructional Objectives:

1. Identify types and uses of wire rope and slings.
2. Install wire rope clips properly.
3. Inspect rope, chains, hooks, shackles, and eye bolts for wear.
4. Identify hand signals for lifting and moving loads.
5. Use hand signals for lifting and moving loads.
6. Demonstrate the use of portable hand hoisting equipment.
7. Identify safety precautions necessary when working with rigging equipment.
8. Tie knots and make hitches with fiber rope.
9. Calculate the safe working loads for rigging devices.
10. Demonstrate the proper procedure for rigging pipe and valves.

Learning Activities:

1. Read pages 10-13, 18-23, 45-68, 77-84, 94-95, 98-99, 104-111, in Handbook for Riggers. Be familiar with the charts and know the Rules of Thumb.
2. Examine the rigging equipment on display in your classroom.
3. Observe as your instructor demonstrates how to tie a square knot, a figure eight knot, a bowline knot, and makes a sheet bend, a half hitch, a blackwell hitch, a cat's paw hitch, a rolling hitch and a timber hitch with fiber rope.
4. View the videotapes "Basic Rigging - 1" and "Basic Rigging - 2." (NUS Training Corporation).
5. Give a presentation on a topic assigned by your instructor. Include a visual aid or demonstration.
6. Complete the Rigging Fundamentals Worksheet.

Application Exercises:

1. Install wire rope clips properly.
2. Demonstrate the use of hand signals for lifting and moving loads.
3. Demonstrate the use of portable hand hoisting equipment.
4. Demonstrate the proper procedure for rigging pipe and valves.
5. Tie knots and make hitches with fiber rope.

Evaluation/Checkout:

1. Submit Rigging Fundamentals Worksheet.
2. Submit your checklist of application exercises.
3. Give a presentation on a topic assigned by your instructor. Include a visual aid or a demonstration.
4. Demonstrate your knowledge of the objectives by completing a test.

Competency:

1. Design templets and develop patterns into models.

Instructional Objectives:

1. Layout a cylindrical sleeve.
2. Layout a semicircular tank.
3. Layout a circular sleeve and flange.
4. Describe the design and layout of welded joints.
5. Describe patterns and templets.
6. Develop a templet for a 90 degree, two-piece turn.
7. Develop a templet for a two-piece turn of 32 degrees.
8. Develop a templet for a 90 degree, three-piece turn.
9. Develop a templet for a 90 degree, four-piece turn.
10. Develop a templet for a branch and header of equal diameters.
11. Develop a templet for a branch and header of unequal diameters.
12. Develop a templet for an eccentric branch and header.
13. Develop a templet for a lateral connection of equal diameters.
14. Develop a templet for a lateral connection with unequal diameters.
15. Develop a templet for a 60 degree, true wye.
16. Develop a templet for a blunt head.
17. Develop a templet for an orange peel head.
18. Develop a templet for a concentric reducer.
19. Develop a templet for an eccentric reducer.
20. Develop a templet for a welded combination offset.
21. Develop a templet for a rolling offset.

Learning Activities:

1. Read Units 2, 4-21 in Templet Development for the Pipe Trades.
2. Complete the Review Questions at the end of Units 2, 4-21 in Templet Development for the Pipe Trades.
3. Complete Assignments 2, 4, 6-21 in Templet Development for the Pipe Trades.

Evaluation/Checkout:

1. Submit your answers to the Review Questions from Units 2, 4-21.
2. Submit your completed Assignments from Units 2, 4, 6-21.

Competency:

1. Fabricate pipe intersections through the use of templets.

Instructional Objectives:

1. Fabricate reducers, tees, reduced tees, 90's, and laterals using templets.

Learning Activities:

1. Using the templets developed in Templet Development I, fabricate the following:
    - -- 90 degree, three-piece turn.
    - -- 32 degree, two-piece turn.
    - -- 90 degree, four-piece turn.
    - -- branch and header, equal diameters.
    - -- branch and header, unequal diameters.
    - -- lateral connection, equal diameters.
    - -- lateral connection, unequal diameters.
    - -- concentric reducer.
    - -- eccentric reducer.

Evaluation/Checkout:

1. Submit the pipe fabrications for evaluation.

Competency:
1. Identify piping system valve types and applications.
2. Describe and use different types of packings and gasket materials by appropriate application.
3. Demonstrate the ability to repair/install valves.

Instructional Objectives:
1. Explain the function of valves.
2. Describe the various types of valves.
3. Define terms and abbreviations related to valves.
4. State the common types of materials from which valves are constructed.
5. Identify the various end connections available for valves.
6. Describe the purpose of valve packing.
7. Summarize common reasons for valve failure and recommend repair procedures.
8. Outline the procedures for maintaining and installing valves.
9. Repack a valve.
10. Install valves with threaded ends, butt-welded and socket-welded ends, and flanged ends.
11. Identify the different types of material gaskets are made of.
12. Match gasket composition to its appropriate application.
13. Disassemble, repair, and reassemble a gate valve.

Learning Activities:
1. Read "Piping Pointers" from Crane Company.
2. Read "Choosing the Right Valve" from Crane Company.
3. Read Chapter 5 in Pipe Fitting and Piping Handbook.
4. Read the Packing Information Sheet.
5. Examine valves and/or valve cutaway models on display in your classroom.
6. Complete the Valves Worksheet.
7. View the videotapes "Valve Maintenance 1 and 2" (NUS Training Corporation).

Application Exercises:
1. Repack a valve.
2. Install a valve with a threaded end.
3. Install a valve with a butt welded end.
4. Install a valve with a socket welded end.
5. Install a valve with a flanged end.
6. Disassemble, repair, and reassemble a gate valve.

Evaluation/Checkout:
1. Submit Valves Worksheet
2. Submit your checklist of application exercises.
3. Demonstrate your knowledge of the objectives by completing a test.

Wisconsin VTAE

Pipefitting Competency Profile

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Introduction

A successful apprenticeship includes both hands on and classroom learning. This combination allows the apprentice to practice the skills and technical information learned in the classroom setting through on-the-job application.

This handbook includes a series of recommended application exercises for your apprentice. They coincide with the competencies and learning objectives that are taught in the classroom. The exercises have been developed to give your apprentice the opportunity to practice the skills being taught in the classroom in his or her work setting.

Directions

The exercises are most beneficial when they coincide with the information the apprentice is learning in class. You will receive the dates these topics will be covered in class from your apprentice's instructor. Whenever possible, arrange for the application activities to be completed during those time frames.

The activities must be performed to the individual supervisor's satisfaction. This allows for differences in policies and procedures at different work sites. When the apprentice has completed an activity, indicate that by putting your initials and the date in the appropriate space (can perform, cannot perform). When the apprentice has performed all of the activities listed, sign your name on the line at the bottom of the page and ask the apprentice to do the same. If you wish to make notes regarding the apprentice's performance, do so in the blank section.

Introduction to the Trade IV

Competency:

1. Demonstrate safe and effective use of typical hand and power tools used in the trade.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Demonstrate the safe use of a stationary grinder.			
2. Demonstrate the safe use of a portable grinder.			
3. Demonstrate the safe use of a metal-cutting band saw.			
4. Bevel pipe with a grinder.			
5. Cut, ream, and thread pipe with a threading machine.			

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Brazing and Soldering

Competency:
1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a joint.
3. Demonstrate the ability to silver braze joints and silver braze copper to a steel joint.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Light and adjust the air-acetylene torch.			
2. Clean, flux, and solder a joint with the air-acetylene torch.			
3. Soft solder with the oxyacetylene torch.			
4. Silver braze a tube and fitting with an oxyacetylene torch.			
5. Silver braze a copper to a steel joint.			

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Chemical Handling

Competency:

1. Demonstrate the ability to withdraw chlorine and/or caustic soda from containers.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Use the proper procedure to withdraw chlorine and/or caustic soda from containers.	________	________	________

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Hot Water Heating Systems

Competency:
1. Demonstrate the ability to maintain a hot water heating system.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Troubleshoot a hot water heating system that is not operating properly.			
2. Install a pressure reducing valve on a hot water heating system.			
3. Install a stop valve on a hot water heating system.			
4. Install a safety relief valve on a hot water heating system.			

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Hydraulics II

Competency:
1. Demonstrate the ability to clean and inspect a reservoir.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Clean and inspect a vented reservoir.	________	________	________

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Hydraulics III

Competency:
1. Demonstrate the ability to work with pipe/tube/hose used in hydraulic systems.
2. Demonstrate the ability to install seals for hydraulic components.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Demonstrate the ability to replace a reusable hose end.			
2. Demonstrate the ability to install an O-ring.			
3. Demonstrate the ability to install a seal.			
4. Demonstrate the ability to install a packing.			
5. Demonstrate the ability to cut, flare, bend, swage, and ream tubing.			

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Hydraulics IV

Competency:
1. Demonstrate the ability to repair a hydraulic cylinder.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Demonstrate the ability to disassemble, inspect, and reassemble a hydraulic cylinder.	________	________	________
2. Demonstrate the ability to test a cylinder for internal and external leakage.	________	________	________

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Hydraulics V

Competency:
1. Demonstrate the ability to repair/install hydraulic controls.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Demonstrate the ability to disassemble, inspect, and reassemble a pressure control valve.			
2. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve.			
3. Demonstrate the ability to disassemble, inspect, and reassemble a flow control valve.			

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Hydraulics VI

Competency:
1. Demonstrate the ability to repair/install hydraulic pumps.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Demonstrate the ability to disassemble, inspect, and reassemble a gear pump.	________	________	________
2. Demonstrate the ability to disassemble, inspect, and reassemble a pressure compensated variable displacement pump.	________	________	________

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Hydraulics VIII

Competency:
1. Demonstrate the ability to troubleshoot and maintain hydraulic systems.
2. Demonstrate the ability to diagnose and test hydraulic systems.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Demonstrate the ability to perform general maintenance procedures on a hydraulic system.	________	________	________
2. Demonstrate the ability to change hydraulic fluid and filters.	________	________	________
3. Demonstrate the ability to test a hydraulic pump.	________	________	________
4. Demonstrate the ability to locate a problem in a hydraulic system.	________	________	________
5. Demonstrate the ability to test a relief valve.	________	________	________
6. Demonstrate the ability to test a control valve.	________	________	________
7. Demonstrate the ability to test an actuator.	________	________	________

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Insulation

Competency:

1. Demonstrate the ability to repair and install insulation.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Install/repair insulation on piping in a process steam system.			
2. Install/repair insulation on valves and fittings in a process steam system.			

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Pipe Hangers and Supports

Competency:

1. Demonstrate the ability to install/fabricate hanger and support setups.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Install masonry anchors properly.			
2. Install a rod hanger.			
3. Fabricate a bracket to given dimensions.			

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Pipe Welding I

Competency:
1. Demonstrate the ability to use welding setup equipment.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Demonstrate the use of internal and external line-up clamps.	________	________	________
2. Demonstrate the use of center finders and contour markers.	________	________	________
3. Demonstrate the use of a wrap-around.	________	________	________
4. Demonstrate the use of two-hole pins.	________	________	________
5. Demonstrate the use of back-up rings.	________	________	________

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Pneumatics II

Competency:
1. Demonstrate the ability to inspect a pneumatic system for leaks.
2. Demonstrate the ability to install a drain trap in a pneumatic system.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Check a pneumatic system for leaks.	________	________	________
2. Install a drain trap in a pneumatic system.	________	________	________

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Pneumatics III

Competency:
1. Demonstrate the ability to repair/install a pneumatic cylinder.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Repair/install a pneumatic cylinder.	________	________	________

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Pneumatics IV

Competency:

1. Demonstrate the ability to disassemble, inspect, and reassemble a directional control valve in a pneumatic system.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Disassemble, inspect, and reassemble a directional control valve in a pneumatic system.	________	________	________

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Pneumatics V

Competency:

1. Demonstrate the ability to repair/install a pressure regulator in a pneumatic system.
2. Demonstrate the ability to repair/install an air line filter in a pneumatic system.
3. Demonstrate the ability to repair/install a lubricator in a pneumatic system.
4. Demonstrate the ability to repair/install a FRL unit in a pneumatic system.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Repair/install a pressure regulator in a pneumatic system.			
2. Repair/install an air line filter in a pneumatic system.			
3. Repair/install a lubricator in a pneumatic system.			
4. Repair/install a FRL unit in a pneumatic system.			

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Pneumatics V

Competency:

1. Demonstrate the ability to repair/install a pressure regulator in a pneumatic system.
2. Demonstrate the ability to repair/install an air line filter in a pneumatic system.
3. Demonstrate the ability to repair/install a lubricator in a pneumatic system.
4. Demonstrate the ability to repair/install a FRL unit in a pneumatic system.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Repair/install a pressure regulator in a pneumatic system.			
2. Repair/install an air line filter in a pneumatic system.			
3. Repair/install a lubricator in a pneumatic system.			
4. Repair/install a FRL unit in a pneumatic system.			

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Process Pipe Drafting II

Competency:
1. Interpret drawings of pipe and fitting assemblies.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Trace runs of pipe and identify valves, fittings, pumps, and tanks.	________	________	________
2. Use specifications to obtain information from drawings.	________	________	________
3. Calculate the needed dimensions and elevations in drawings.	________	________	________

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Process Pipe Drafting III

Competency:
1. Interpret the information on flow diagrams, elevation drawings, section drawings, and piping plans.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Use flow diagrams, elevation drawings, and section cuts to trace given runs of pipe.	________	________	________
2. Use flow diagrams, elevation drawings, and section cuts to interpret information about given runs of pipe.	________	________	________

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Process Pipe Drafting IV

Competency:

1. Describe the layout of an isometric drawing.
2. Explain the purpose and layout of a spool drawing.
3. Read a specifications book and develop a material list for a specific job.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Interpret information found on isometric drawings.	________	________	________
2. Interpret information found on spool drawings.	________	________	________
3. Use a specifications book and an isometric drawing and construct a material list for a specific job.	________	________	________

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Process Piping Fabrication III

Competency:
1. Fabricate piping offsets.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Fabricate a simple offset.	________	________	________
2. Fabricate a two-pipe equal spread offset.	________	________	________
3. Fabricate a rolling offset.	________	________	________

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Process Piping Fabrication IV

Competency:
1. Use clamps and aligning devices employed in the trade.
2. Fabricate miters, tees, saddles, laterals, and elbows.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Demonstrate the use of internal and external line-up clamps.			
2. Use a level to align pipe.			
3. Demonstrate the use of a hi-lo gauge.			
4. Demonstrate the use of a two-hole leveler.			
5. Demonstrate how to square a flange and use a pipe flange aligner.			
6. Demonstrate the use of a wrap-around.			
7. Demonstrate the use of center finders.			
8. Lay out ordinates on pipes.			
9. Lay out and cut miters of 11 1/4, 15, 22 1/2, and 45 degrees.			

10. Fabricate 2-, 3-, 4-, and 5- piece mitered elbows. ________ ________ ________

11. Lay out, cut and align saddles. ________ ________ ________

12. Fabricate tees, laterals, and Y fittings. ________ ________ ________

13. Demonstrate the use of a contour marker to lay out elbows, laterals, and saddles. ________ ________ ________

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Process Steam Systems II

Competency:
1. Demonstrate the ability to install steam boiler fittings and accessories.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Install a safety valve on a steam boiler system.			
2. Install a water column on a steam boiler system.			
3. Install a stop valve on a steam boiler system.			
4. Install a blowdown valve on a steam boiler system.			
5. Install a swing check valve in the feedwater line of a steam boiler system.			

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Process Steam Systems III

Competency:
1. Demonstrate the ability to install feedwater devices.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Install a feedwater regulator.	________	________	________
2. Install a feedwater pump.	________	________	________

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Process Steam Systems IV

Competency:
1. Repair and maintain steam heating systems.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Install a pressure reducing valve.			
2. Install a boiler water feeder or a low water cut-off device.			
3. Repair/replace a gate valve on a steam heating system.			
4. Construct a Hartford return connection for a steam heating system.			
5. Repair/maintain an expansion joint.			
6. Troubleshoot a steam heating system, describing in detail, symptoms, their probable causes and corresponding remedies.			

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Process Steam Systems V

Competency:

1. Demonstrate the ability to repair and install steam traps.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Repair and install a mechanical trap.			
2. Repair and install a thermostatic trap.			
3. Repair and install a thermodynamic trap.			
4. Calculate a trap sizing problem.			

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Refrigeration and Air Conditioning III

Competency:

1. Demonstrate the ability to install common refrigeration accessories.
2. Demonstrate the ability to evacuate a refrigeration system.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Install a filter-drier with flare fittings.			
2. Install a filter-drier with sweat fittings.			
3. Install a liquid indicator with flare fittings.			
4. Attach a gauge manifold set using a stem type service valve.			
5. Install a line tap access valve.			
6. Install an access core type service valve.			
7. Pressure check an air conditioning system.			
8. Fill a charging cylinder.			
9. Evacuate a refrigeration system.			

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Refrigeration and Air Conditioning IV

Competency:
1. Demonstrate the ability to flare, bend, and swage tubing.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Make a single flare with a compression type flaring block.			
2. Make a single flare with a generating type flaring block.			
3. Make a double flare.			
4. Make a swage joint.			
5. Make a 90 degree bend.			
6. Make a 180 degree bend.			
7. Make a 45 degree offset.			

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Refrigeration and Air Conditioning V

Competency:

1. Demonstrate the ability to use the air-acetylene and oxyacetylene torch.
2. Demonstrate the ability to clean, flux, and soft solder a swage joint.
3. Demonstrate the ability to silver braze swage joints and silver braze a copper to a steel joint.

Application Exercises:	**Can Perform (Initial)**	**Cannot Perform (Initial)**	**Date**
1. Light and adjust the air-acetylene torch.			
2. Light and adjust the halide torch leak detector using propane.			
3. Light and adjust the halide torch leak detector using air-acetylene.			
4. Clean, flux, and solder a swage joint.			
5. Solder an inverted swage joint.			
6. Solder a horizontal swage joint.			
7. Soft solder with the oxyacetylene torch.			
8. Silver braze an upright swage joint.			
9. Silver braze an inverted swage joint.			
10. Silver braze a horizontal swage joint.			
11. Silver braze a copper to a steel joint.			

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Apprentice's signature ______________________________

Refrigeration and Air Conditioning VI

Competency:

1. Demonstrate the ability to pressurize a refrigeration system with dry nitrogen.
2. Demonstrate the ability to use soap bubbles, a halide torch, and an electronic leak detector to find a refrigerant leak.
3. Demonstrate the ability to vapor charge and liquid charge a refrigerant system.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Leak check using soap bubbles.	________	________	________
2. Leak check using a halide torch.	________	________	________
3. Leak check using an electronic detector.	________	________	________
4. Pressurize system with dry nitrogen and leak check.	________	________	________
5. Vapor charge using a charging cylinder.	________	________	________
6. Vapor charge using a refrigerant cylinder.	________	________	________
7. Liquid charge using a charging cylinder.	________	________	________
8. Liquid charge using a refrigerant cylinder.	________	________	________

Supervisor's signature ______________________________

Apprentice's signature ______________________________

Rigging

Competency:

1. Demonstrate basic safe practices associated with rigging.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Install wire rope clips properly.			
2. Demonstrate the use of hand signals for lifting and moving loads.			
3. Demonstrate the use of portable hand hoisting equipment.			
4. Demonstrate the proper procedure for rigging pipe and valves.			
5. Tie knots and make hitches with fiber rope.			

Supervisor's signature ________________________

Apprentice's signature ________________________

Valves, Packings, and Gaskets

Competency:

1. Describe and use different types of packings and gasket materials by appropriate application.
2. Demonstrate the ability to repair/install valves.

Application Exercises:	Can Perform (Initial)	Cannot Perform (Initial)	Date
1. Repack a valve.	________	________	________
2. Install a valve with a threaded end.	________	________	________
3. Install a valve with a butt welded end.	________	________	________
4. Install a valve with a socket welded end.	________	________	________
5. Install a valve with a flanged end.	________	________	________
6. Disassemble, repair, and reassemble a gate valve.	________	________	________

Supervisor's signature ______________________________

Apprentice's signature ______________________________